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ARTS IIIA Terminal Baseline Research Report

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16. Abstract

This report provides baseline measurements on the Automated Radar Terminal System (ARTS) IIIA. Researchers developed a set of measurements useful for evaluating the efficiency and effectiveness of terminal air traffic control automation systems. These measurements followed six high-level operational constructs: Safety, Capacity, Performance, Workload, Usability, and Simulation Fidelity. To collect these measurements for the ARTS IIIA, we conducted an air traffic control simulation using four sectors of Boston Terminal Radar Approach Control (TRACON) airspace with a traffic volume representing a 90th percentile day. Twelve controllers from Boston TRACON served as participants in the 3-week study. Recordings from the Target Generation Facility and Continuous Data Recording (CDR) systems provided objective data for measures such as the average number of aircraft controlled and the average number of data entries. Questionnaires and expert observer rating forms provided subjective data for measures such as the average controller workload and controller performance.

This report provides statistics at several levels of specificity: aggregated across all sectors and runway configurations, by individual sector and runway configuration, and by 15-min intervals. Data from the study are intended to provide a meaningful representation of the TRACON controller position. We provide guidance on using these baseline measurements to examine the effectiveness and efficiency of future terminal automation systems. This guidance includes recommendations for merging quantitative statistics with controller opinion. We also include recommendations regarding the appropriate and inappropriate use of these data.

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Executive Summary

This study provides baseline measures on the Automated Radar Terminal System (ARTS) IIIA. The Federal Aviation Administration had previously identified six high-level operational constructs to be used in the assessment of en route air traffic control systems: Safety, Capacity, Performance, Workload, Usability, and Simulation Fidelity. Engineering research psychologists from the Human Factors Branch (ACT-530) adapted these constructs to the terminal domain and based this assessment of the ARTS IIIA on them.

The researchers created two simulation scenarios of Boston Terminal Radar Approach Control (TRACON) airspace. The air traffic patterns and airspace characteristics of these scenarios were representative of four sectors at Boston TRACON and used two runway configurations. Each scenario used a 90^{th} percentile day for traffic volume. The four simulated sectors were Initial Departure, South, Rockport, and Final One.

The Target Generation Facility and ARTS IIIA Continuous Data Recording tapes provided objective measures of controller and system performance. Controller and expert observer questionnaires provided subjective data. This study contains statistics at several levels of specificity: across the four sectors, by individual sectors, and by 15-min intervals.

This report presents guidance on using the baseline measures to verify the effectiveness and efficiency of a future terminal air traffic control system. It recommends a process to merge quantitative statistics with controller expert opinion in order to compare the baseline and future systems. The data reported here should only be used for these purposes.

1. Introduction

As it moves into the 21st century, the Federal Aviation Administration (FAA) will specify, prototype, develop, test, and deploy new air traffic control (ATC) automation systems for the terminal domain. These systems will replace or augment systems currently in use. This report provides baseline data on the efficiency and effectiveness of the Automated Radar Terminal System (ARTS) IIIA that may be useful throughout this process.

1.1 Background

As part of an earlier effort to provide baseline data for the current en route system, the Air Traffic Advanced Automation System Requirements Organization, ATR-320, identified six high-level operational constructs useful for system comparisons, as follows:

a. Safety represented the extent to which the system maintained, enhanced, or degraded relative safety.

b. Capacity measured aspects of traffic throughput in a specific sector of airspace during a specified time.

c. Performance involved controller interaction with the system through the computer-human interface (CHI).

d. Workload represented subjective evaluations of cognitive task demands of ATC simulations.

e. Usability consisted of user opinions regarding the acceptability of the CHI, controls, displays, and other equipment items.

f. Simulation Fidelity represented characteristics of the air traffic mix and the perceived fidelity of the simulation scenarios.

Galushka, Frederick, Mogford, and Krois (1995) developed a set of baseline measures based on these constructs through meetings with en route controllers. During these sessions, they reviewed all available metrics and identified a set that was useful for system comparisons. They based some variables in their original set on work by Buckley, DeBaryshe, Hitchner, and Kohn (1983); Hedge, Borman, Hanson, Carter, and Nelson (1993); and Sollenberger, Stein, and Gromelski (1997). These variables served as the basis for the Plan View Display Baseline (PVD) study conducted in 1995.

1.2 Purpose

The goal of the current study was to identify and collect baseline measures that would be effective indicators of ARTS IIIA performance and suitable for comparisons with future terminal ATC automation systems. To accomplish this goal, engineering research psychologists from the FAA William J. Hughes Technical Center, Human Factors Branch, ACT-530, and personnel from Boston Terminal Radar Approach Control (TRACON) reviewed the measures used in the en route baseline to assess their applicability to the terminal domain. They refined several

measures and added new measures specific to terminal ATC operations. The final set of terminal baseline measures contained both objective and subjective elements.

Objective measures were quantitative metrics that were pertinent to the ATC mission and realistic concerning ATC operations. Subjective measures were controller and expert observer opinions and perceptions collected from questionnaires and rating scales.

The measures collected during the terminal baseline simulations provide indices of relative levels of operational acceptability and cannot be used in isolation. Variations between the ARTS IIIA and other systems on the reported variables must be analyzed in the context advised in this document to derive valid system comparisons. Any other use of these data might prove misleading and invalid.

2. Method

This study involved Full Performance Level terminal controllers working four simulated sectors of Boston TRACON airspace. A variety of data sources provided objective and subjective measures of controller and system performance. These measures followed the six high-level operational constructs identified by ATR-320.

Three engineering research psychologists and a data collection specialist managed the activity and collected objective and subjective data. Specialists from the TGF and the ARTS IIIA Laboratory provided simulation hardware and software support.

2.1 Participants

Twelve Boston TRACON controllers participated in groups of four, one group per week, for 3 consecutive weeks. The average age of the controllers was 34.0 (*SD* = 3.87) years with an average of 12.3 (*SD* = 2.93) years of experience controlling traffic and an average of 6.7 (*SD* = 3.70) years of experience with the ARTS IIIA. The controllers were current and knowledgeable on the four sectors used in this study.

Three Boston TRACON supervisors served as expert observers, one per week. They assisted with data collection and made performance evaluations. Their primary responsibilities were to complete the Observer Evaluation Form (Appendix A) and to provide procedural and operational expertise when necessary.

Sixteen Simulation Operation Pilots (SIMOPs) from the Technical Center Target Generation Facility (TGF) controlled simulated aircraft targets. The SIMOPs provided voice communications and made heading, altitude, and speed changes using special computer workstations. Most SIMOPs were not professional pilots but had training in aviation terminology, were familiar with ATC procedures, and had received training on the Boston TRACON airspace.

2.2 Boston Terminal Radar Approach Control Airspace

An imaginary and approximate line in space defines the Boston TRACON airspace. It begins over Providence, RI; bears north to Gardner, MA; then east to Plum Island, MA. This boundary line continues southeast to a point 25 nmi east of Boston (SCUPP Intersection); southwest to Plymouth, MA; and west to Providence. The airspace begins at the surface and extends vertically to 14,000 ft. Many areas (called shelves), where altitudes of control can vary based on sector, are found along the outer edges of the airspace. The Boston TRACON controls all Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) traffic that either originates, terminates, or transits through the airspace. Boston TRACON has responsibility for the Logan International Airport (BOS) and many satellite airports in the metropolitan Boston area.

At the heart of the Boston TRACON airspace is the Boston Class B airspace. The airspace is centered at BOS and the Boston Very High Frequency Omnidirectional Radio Range (VOR) and it extends approximately 20 nmi in all directions. The altitude floor of Class B airspace varies depending on the distance from BOS, and the altitude ceiling is 7000 ft in all areas. The purpose of Class B airspace is to prevent collisions between VFR aircraft operating in proximity to BOS and high-performance turboprop or jet aircraft also using the airport.

Boston TRACON is composed of eight sectors. The amount of airspace controlled by a sector can vary based on workload, on whether the sector is combined with another sector, or on the runway configuration being used at BOS. Each runway configuration has an arrival and departure flow that is specific to that configuration. Noise abatement and environmental concerns partially determine these flows. Supervisors at Boston TRACON routinely combine sectors when workload circumstances warrant.

For the current study, specialists from the Technical Center developed simulations of four sectors based on actual Boston TRACON sectors. Descriptions of the sectors at Boston TRACON follow, and any differences between the actual and simulated sectors are noted.

a. Initial Departure. All aircraft that depart BOS use the Initial Departure Sector. Controllers vector aircraft per a Logan-Nine Standard Instrument Departure procedure, which outlines departure instructions and noise abatement procedures. In this simulation, the Initial Departure Sector was combined with the Lincoln Sector, which is a westbound departure corridor sector and an inbound sector for arrivals from the southwest. (Controllers hand off all arrival aircraft from the southwest to the Final One Sector for sequencing and approach clearances to BOS.)

b. South. The South Sector receives departures from BOS, including both jet and propeller traffic departing southbound. In this simulation, the South Sector was combined with the Plymouth Sector, which is predominantly a southbound departure corridor and an inbound sector for arrival flights planned over Providence or from the Cape Cod area. (Controllers vector arrival aircraft to runways based on the runway configuration in use and their preference. Controllers hand off all arrival aircraft to the Final One Sector for sequencing and issuing approach clearances.)

c. Rockport. The Rockport Sector is mainly a north- and northeast-bound departure corridor and an inbound sector for arrival flights planned over Gardner, MA; Manchester and Pease, NH; or the Boston overseas arrival fix, 25 nmi east of the airport. The Rockport Sector receives departures from the Initial Departure Sector, including all jet and propeller traffic departing to the north and northeast. Controllers vector arrival aircraft to the runway in use and then hand off the aircraft to the Final One Sector for sequencing and issuance of approach clearances.

d. Final One. Final One is the final approach control position where controllers issue all approach clearances for BOS and subsequently transfer the aircraft to the Tower Local Control for landing clearances. This position does not typically control departure traffic, though coordination for such operations may be requested. Controllers may vector an aircraft to any runway included in a particular configuration for a more efficient use of airspace or runway utilization. In this simulation, the Final One and Final Two Sectors were combined.

Controller participants received a simulation training package before the study. This package contained detailed information on the airspace, runway configurations, procedures, and controller actions that they would use in the simulation. The briefing package also included the Background Questionnaire and maps of the airspace and runway configurations. Appendix B contains a copy of this package.

2.3 Simulation Scenarios

Simulation specialists from the System Simulation and Support Branch (ACT-510), in collaboration with Boston TRACON personnel and engineering research psychologists from ACT-530, prepared two traffic scenarios that were representative of the traffic patterns and characteristics of the four sectors. These scenarios used two different runway configurations: Land 27/22L - Depart 22R and Land 4R/L - Depart 9. These scenarios required staffing of all four sectors, though this staffing level was lighter than a typical 90th percentile day at Boston TRACON. There, two controllers typically staff the Final One sector, and one controller staffs a satellite position, for a total of six controllers. Personnel and equipment availability limited the staffing that could be used in the simulation.

The traffic volume in the scenarios was equivalent to a 90th percentile day at Boston TRACON with density varying from moderate to heavy. Researchers believed that this traffic volume would be sufficient to functionally exercise the ARTS IIIA. Simulation specialists at the Technical Center developed the scenarios from Continuous Data Recording (CDR) tapes recorded at Boston TRACON on July 25, 1995, between the hours of 1400 and 1600 local time. Specialists from the Boston TRACON training department verified and rated the scenarios and tested them in the Technical Center laboratories. Both scenarios contained a mix of jet and propeller-driven aircraft flying IFR flight plans that either originated or terminated service at BOS. Including VFR flight plan airçraft or overflight aircraft was not technically feasible given the platform and timeframe of the simulation (see Section 4.1.2).

The scenarios originally did not include any special events or unscripted pilot requests so as not to reduce the repeatability of the simulation. The researchers believed that inclusion of these

events could have focused simulation timing and controller preferences on techniques for handling problems rather than on routine ATC operations. However, during the conduct of the simulation, the researchers observed that controller workload was not as high as expected in runs using the 4R/L runway configuration. The research psychologist managing the activity, in collaboration with supervisors from Boston TRACON, decided to increase the taskload by closing one of the runways in this configuration. The researchers introduced this event to increase complexity, add variety to the simulation, and provide a more challenging problem in which to assess controller performance and workload. The researchers believed this change would require additional traffic management especially by arrival sector controllers. This special event occurred as follows: About 45 min into the 90-min run, the expert observer announced that bad weather and poor visibility had caused the closing of the 4L runway. This weather situation forced all traffic to land at the 4R runway for the remainder of the run. Section 3.2.1 describes the effect of this manipulation on controller workload.

2.4 Laboratory Platform

The Technical Center ARTS IIIA Laboratory served as the primary data collection site for this study. Participants controlled traffic using four ARTS IIIA consoles. The expert observer could monitor the traffic situation from a fifth console. The lighting conditions in the laboratory were realistic compared to the levels at Boston TRACON. Specialists from the laboratory ensured that all radar consoles and communication equipment functioned properly.

The TGF provided simulated airspace and targets. Simulation specialists from the TGF ensured that the scenarios ran smoothly and that all simulation equipment functioned properly. SIMOPs from the TGF controlled simulated aircraft using special workstations and made simulated air-ground communications with controllers using the Amecom system. SIMOPs also made simulated ground-ground communications if controllers required coordination with other facilities or sectors.

2.5 Simulation Schedule

The study began the week of September 18, 1995 and continued for 3 consecutive weeks. Each week involved a new group of four controllers and a new expert observer. On the first day of each week, controllers and expert observers received a pretest briefing, a tour of the ARTS IIIA Laboratory, and an introduction to the data collection techniques and equipment. Controller participants received briefings on all laboratory and data collection equipment and procedures. These briefings focused on issues of confidentiality and informed consent, particularly as these issues relate to the audio and video recordings made during the simulation runs. On the second, third, and fourth days of each week, controllers completed two or three simulation runs per day. On the fourth day, controllers received a final briefing. Testing ended on October 5, 1995.

During the 3 weeks of testing, there were 24 successful simulation runs (7 runs during the first, 9 during the second, and 8 during the third week). This resulted in a large data set and a reliable baseline. Laboratory hardware problems forced researchers to abort some runs, which resulted in an uneven number of runs from week to week. Each run lasted 90 min and alternated the two

runway configurations. Each controller staffed a different sector during each run so that they staffed every combination of sector and runway configuration at least once during the week.

2.6 Objective and Subjective Measures

The TGF and CDR systems recorded objective data. These measures focused on quantifying traffic volume, flight duration, traffic characteristics, and other factors in each sector. Another goal for recording objective data was to determine the input/output activity at each sector position to measure how each controller used the system.

Five questionnaires, completed by controllers and expert observers, provided subjective data. The Background Questionnaire, which was part of the Briefing Document (Appendix B), focused on the experience levels and other pertinent data from the controller participants. The Post-Scenario Questionnaire contained queries on perceived overall workload, problem difficulty, self-ratings of performance, and simulation realism. The Final Questionnaire addressed workstation and display ergonomics and included space for written comments. Expert observers rated controller performance using the Observer Evaluation Form developed by Sollenberger et al. (1997) and kept notes on simulation technical problems using the Observer Log. Appendix A provides copies of these four questionnaires.

The researchers used four Workload Assessment Keypads (WAKs) to measure subjective controller workload using the Air Traffic Workload Input Technique (ATWIT) (Stein, 1985). Each WAK consisted of a box with small, lighted keys (numbered 1 through 7) and a tone generator. Each WAK was connected to one of four laptop computers that controlled the timing of prompts and recorded data. The WAKs were positioned on the ARTS IIIA console and could be repositioned according to controller preference. Every 5 min during a simulation run, each WAK emitted a short beep and illuminated its lights, prompting controllers to rate their workload from 1 (low) to 7 (high). Entry of a workload rating caused the WAK lights to extinguish until the next prompt. The laptop computers recorded these ratings automatically. If a controller did not enter a workload rating, the lights remained illuminated for 20 seconds and then extinguished. In such cases, the laptop computers recorded a workload rating of 10 (a missing data code).

Three small video cameras recorded controller activities. Two cameras, positioned above and behind the controllers' workstations, recorded their physical actions (e.g., display adjustments, trackball and keyboard use, and WAK entries) but could not record information displayed on the controllers' screens. A third camera recorded the display of a single ARTS IIIA console showing all four sectors. Videotapes recorded the voices of the controllers. Researchers reviewed the videotapes as part of the data analysis to validate start times, controller positions, and so forth. Researchers also used videotapes to review loss of separation incidents. Appendix C, Table C-1 describes this analysis.

The data sources employed for this testing activity were the

a. Background Questionnaire (completed at the beginning of the week),

b. Post-Scenario Questionnaire (completed after each simulation run),

c. Final Questionnaire (completed at the end of the week),

d. Observer Evaluation Form (completed once per controller during the week),

e. Observer Log (completed during each simulation run),

f. Amecom audio tape from communication system,

g. real-time controller workload rating (ATWIT),

h. videotape with audio,

i. TGF data recording, and

j. CDR tape.

The definitions for each of the baseline measures, including their categorization by operational construct and the rationale for use in baselining the ARTS IIIA, are as follows. (The source for each measure is usually indicated in parentheses.)

a. Safety

1. Operational Errors was a basic safety measure representing loss of applicable separation minima. (TGF)

2. Conflict Alerts was a system-initiated display warning the controller of imminent aircraft-to-aircraft conflicts. The conflict alert system had features to minimize the false alarm rate in the terminal area. (CDR)

3. Other Safety-Critical Issues were derived from expert observer comments on system safety issues and deficiencies. (Observer Log)

b. Capacity

1. Aircraft Under Control was a basic capacity measure. It represented a tally of traffic under track control. (TGF)

2. Average Time in Sector (Handoff to Handoff) was a measure of sector efficiency. Increased time in sector may have indicated less efficient movement of aircraft in the airspace or controller-induced delay vectoring due to a traffic overload situation. (TGF)

3. Average Time in Sector (Arrivals) was a measure of arrival sector efficiency. (TGF)

4. Average Time in Sector (Departures) was a measure of departure sector efficiency. (TGF)

5. Aircraft Spacing on Final Approach was a measure of the efficiency of the traffic flow on final approach. This measure represented the distance from an aircraft over the middle marker to the aircraft immediately trailing it. Large and variable spacing could indicate differences in control style and changes in traffic density. (TGF)

6. Minutes Between Arrivals was a measure of the traffic density on final approach. This measure represented the minutes that elapsed between consecutive aircraft

passing over the middle marker. Shorter times between landings could indicate increased traffic density. (TGF)

7. Altitude Assignments Per Aircraft provided a ratio of total altitude assignments to number of aircraft under control. It was an indicator of the relative efficiency of aircraft movement through the sector. Controllers commonly relied on vertical separation in preference to vectoring solutions. This resulted in level-offs and climb or descent delays. A decrease in altitude assignments, with a corresponding decrease in climb or descent delays, could indicate greater efficiency. An increase in altitude assignments with a corresponding increase in climb or descent delays and level-offs could indicate less efficiency. (TGF)

c. Performance

1. Data Entries was a relative measure of data entry workload for the controller position. (CDR)

2. Data Entry Errors was a relative measure of data entry effectiveness. Significant variations may indicate difficult message syntax, awkward entry device layout, or other possible factors. (CDR)

3. Number of Altitude, Speed, and Heading Changes represented the efficiency of sector operations for total number of clearances issued in these three categories. Significant variation in relative proportions could show controllers had changed their method for handling traffic. These counts were based upon aircraft-related data entries at the SIMOP positions. (TGF)

4. ATC Services were measures of the quality of ATC services and indicators of system performance. Controllers made ratings on the Post-Scenario Questionnaire that ranged from 1 (low) to 8 (high). The specific items composing the measure were the rated quality of ATC services from (a) the pilot's perspective and (b) the controller's perspective.

5. Human Capabilities for ATC were measures representing human capabilities used by the controller in performing ATC functions. Expert observers made ratings on the Observer Evaluation Form that served as indicators of operator efficiency and effectiveness based on a 1 (low) to 8 (high) scale. They were encouraged to comment, and a form was provided for that purpose. The rating scales are more completely described in Sollenberger et al. (1997). The specific items composing the measure assessed

   a) how well the controller maintained safe and efficient flow,

   b) how well the controller maintained attention and vigilance,

   c) how well the controller prioritized,

   d) how well the controller communicated and informed, and

   e) the level of the controller's technical knowledge.

d. Workload

1. Workload Per Aircraft was a measure that estimated the amount of workload expended per aircraft. Subjective workload ratings corresponded closely to the number of aircraft tracked throughout the baseline scenarios. (ATWIT and TGF)

2. Average Workload was the mean subjective workload reported by controllers, by sector, across the entire simulation. Workload is the human response to the demands or task loads produced by the airspace system. Human response consisted of observable control actions and cognitive activity. (ATWIT)

3. Post-Run Workload was a measure of average workload for the scenario as part of the Post-Scenario Questionnaire. The rating scale ranged from 1 (low) to 8 (high).

4. Communication Workload was the mean number of push-to-talk communications per aircraft worked. This measure detected changes in communication workload needed to control aircraft. Increased communications per aircraft may have indicated a less efficient automation interface. Conversely, increased communications per aircraft may have represented greater latitude for controllers to maneuver aircraft and initiate actions. (TGF)

5. Data Entry Workload was the mean number of data entries per aircraft worked and detected changes in workload required to control aircraft. (CDR and TGF)

e. Usability

1. ARTS IIIA Console were measures of the usability of the system as rated by controllers. These ratings ranged from 1 (low) to 8 (high). The specific items composing these measures on the Final Questionnaire assessed

   a) how easily the controller can access controls;

   b) how intuitively controllers operate controls;

   c) how easily controllers use the keyboard;

   d) how easily controllers read radar and map displays;

   e) how easily controllers understand radar and map displays;

   f) the sufficiency of the workstation space;

   g) how well equipment, displays, and controls support efficient ATC;

   h) the amount of limitation imposed by equipment, displays, and controls;

   i) the overall effectiveness of equipment, displays, and controls; and

   j) the overall quality of interaction with equipment.

f. Simulation Fidelity

1. Traffic Characteristics was a measure representing the scenario length, number of flights, type of flight (arrival, departure, or overflight), and type of aircraft (jet or propeller). It was a characterization of the simulation scenario. (TGF)

2. Perceived Representativeness was a measure of the controllers' perceived fidelity of the simulation scenarios for the four sectors. It was a check on the realism of the simulation. These ratings ranged from 1 (low) to 8 (high). The items comprising this measure on the Post-Scenario Questionnaire were

   a) realism,

   b) technical problems, and

   c) problem difficulty.

3. Summary Data

The purpose of this study was to develop a baseline of performance data typifying the existing ARTS IIIA system. It was the intention that these data be used for comparisons with new systems designed for the terminal environment. If the conditions of this study were duplicated, it should be possible to compare the systems using the measures specified in this report. However, it is not expected that the measures described and enumerated here represent a final set. Operational and human engineering judgement should be employed in their application.

By itself, this report has limited value, except as an exercise in baselining an operational FAA system. It should be treated as a database of information that forms the foundation for future baselining efforts and system comparisons. When future systems are measured using the same approach, then useful comparisons and insights will be gained about their strengths and weaknesses using a basis of objective and subjective measures.

3.1 Measure Summary Data

Appendix C, Table C-1 provides a summary of all measures aggregated across all sectors, intervals, and corresponding simulation runs. It also provides short descriptions of each measure. For some measures, the table presents the aggregated data and refers to more detailed information contained in Tables C-2 through C-24. This additional information is intended to augment the aggregate data (e.g., to assess differences between sectors, runway configurations, or time intervals). For some measures, Table C-1 indicates that aggregate data are not meaningful and refers to other tables containing the pertinent data.

Appendix D lists the narrative responses made by the controller participants on the Final Questionnaire. These items address issues of usability and performance of the ARTS IIIA and simulation fidelity.

3.2 Sector Summary Data

Tables C-2 and C-4 provide the means for each sector and runway configuration, aggregated across 15-min intervals and simulation runs. Table C-2 provides the means for quantitative data and C-4, for questionnaire data. Some measures contain references to other tables providing additional data. Tables C-3 and C-5 provide the standard deviations at the sector summary level

for the quantitative and questionnaire measures. Table C-6 provides the mean number of ARTS entries for each sector, runway configuration, and entry type aggregated across 15-min intervals and simulation runs.

3.2.1 Workload Manipulation

Starting in the second week of the study, researchers introduced a workload manipulation into the runs using the 4R/L runway configuration. Approximately halfway through each run, poor visibility forced the closing of the 4L runway. Researchers examined the effect of this manipulation on the workload of the controller staffing the Final One Sector and compared the means for the 3 simulation weeks for each variable making up the Workload construct (workload per aircraft, average workload, post-run workload, communication workload, and data entry workload).

An analysis of variance (ANOVA) revealed a significant main effect of week on workload per aircraft, $F(2, 21) = 32.69, p < .0001$; average workload, $F(2, 21) = 28.79, p < .0001$; post-run workload, $F(2, 20) = 6.86, p < .01$; and communication workload, $F(2, 18) = 9.16, p < .01$. There was no significant effect on data entry workload. The workload manipulation began in the second week so an effect of this manipulation would appear as a difference between the first week and the second 2 weeks. The Tukey-HSD procedure was used to further analyze these main effects and determine which weeks differed.

These results show that the main effects of week are unlikely to be due to the workload manipulation. For the workload per aircraft, average workload, and post-run workload variables, the main effect was due to higher workload ratings given by the controllers in Week 3. It is unlikely that this effect is due to the workload manipulation because controllers in Week 2 also experienced the manipulation but did not give higher workload ratings than controllers in Week 1. For the communication workload variable, the main effect is due to increased numbers of push-to-talk communications made by the controllers in Week 2. Again, this effect is probably not due to the workload manipulation. Controllers in Week 3 also experienced the manipulation but did not make reliably more communications than controllers in Week 1. The workload manipulation does not appear to have affected overall workload on any of the variables included in the Workload construct. Because of this, the values reported in Appendix C were collapsed across the 3 simulation weeks.

Examination of the 15-min interval workload data revealed that the weather manipulation primarily changed the pattern of workload ratings rather than the absolute level. Figure 1 shows the average workload ratings by 15-min intervals as given by controllers working the Final One Sector in the 4R/L runway configuration. In Week 1, workload ratings stayed the same or decreased between 45 to 60 min into the simulation. In Weeks 2 and 3, however, workload ratings stayed the same or increased during this interval, corresponding to the onset of the weather manipulation. Tables C-7 and C-8 provide a subset of the data by week that can be used to further examine the effect of this manipulation.

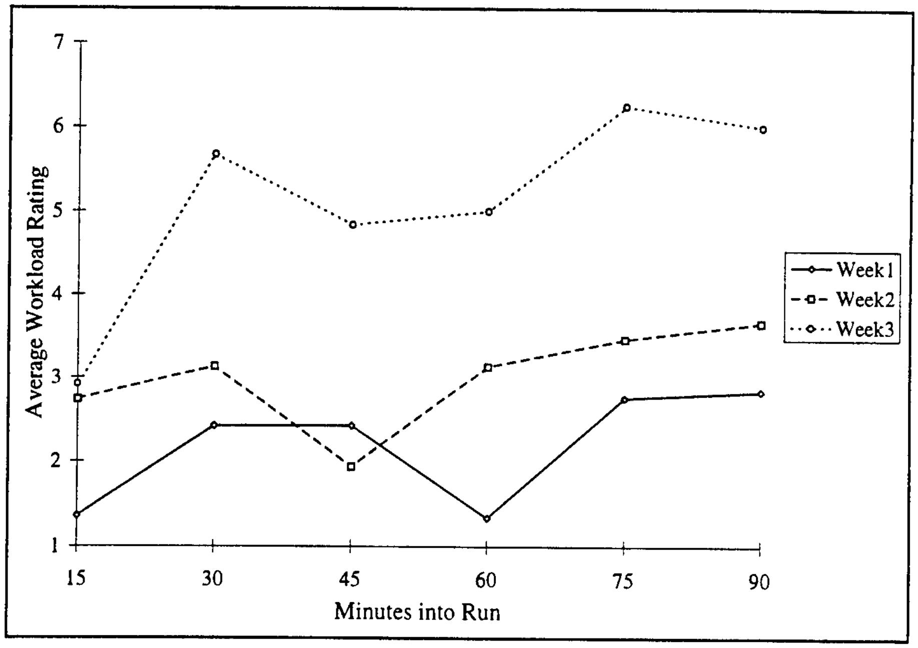

Figure 1. Workload ratings by minutes into run for each week.

3.3 15-Minute Interval Summary Data

For some measures, it was operationally meaningful to separate sector-level statistics by 15-min intervals. For example, the WAKs collected workload data every 5 min during the simulation run. Researchers used these to create mean ratings for each 15-min interval. Tables C-9 through C-16 provide these means for each 15-minute interval, sector, and runway configuration aggregated across simulation runs. Tables C-17 through C-24 provide standard deviations for these data.

4. Recommendations

This section includes information on the application of these data for system comparisons. It also discusses refinements to data recording and analysis procedures that future baseline studies should use. Finally, it addresses limitations or constraints that apply when using these data.

4.1 Use of Baseline Data for System Comparisons

This section provides guidance on using this baseline measure methodology to make comparisons with future systems. The approach taken is to use quantitative baseline measure data in combination with qualitative information to assess future automation systems.

The current study used information garnered from controllers and expert observers to verify any issues or concerns identified through the analysis of the quantitative data. This information can also identify other issues or concerns not captured in the quantitative measures. It may also be pertinent in the comparison of a future system to the current baseline system. The current study obtained this information during simulation run debriefings and a post-simulation caucus.

The current study represents the first two steps of a five-step, high-level approach as follows:

1. Collect sufficient data on the current system to provide stable estimates on all specified operational constructs and baseline measures.

2. Reduce and analyze the data collected and complete the tables at each level of detail.

3. Collect the same data for the future system using the same airspace, simulation scenarios, controllers (if possible), and other aspects of the simulation that might otherwise work as intervening or confounding variables.

4. Complete the identical data reduction and analysis for the future system.

5. Conduct a post-simulation caucus with the controllers and expert observers using the data comparisons as starting points to identify an initial set of issues and concerns. Refer to the data in other detailed tables to augment the analysis of these issues and data contained in observer logs and debriefing materials. Make systematic comparisons between the terminal baseline and the future system, stepping through each quantitative measure. Examine all data in a dynamic fashion to identify related trends that may or may not appear in other operational constructs and measures. This further substantiates or refutes whether a problem exists.

During the caucus, researchers should use consensus-building techniques with the controllers and observers to review and categorize the quantitative comparisons, identify and prioritize significant issues, and assess the viability of potential resolutions. This may require participation of ATC procedures and training specialists. As part of the assessment, it is necessary to verify that a problem is not an artifact of the simulation platform or some other irrelevant variable potentially skewing the comparisons between the two systems.

An important basis for determining whether the future system is comparable to the baseline system is whether the data for any particular measure are statistically equivalent. That is, it must be determined whether the two systems numerically share the same average or have overlapping ranges or confidence intervals. However, statistical equivalence or nonequivalence does not automatically indicate operational equivalence or nonequivalence. Expert judgment must determine this. Results can fall into four categories, as follows:

a. Category 1 involves measures where the baseline and future systems have data that are statistically equivalent and are operationally equivalent.

b. Category 2 involves measures where the baseline and future systems have data that are statistically equivalent but are operationally different.

c. Category 3 involves measures where the baseline and future systems have data that are not statistically equivalent, but the systems are operationally equivalent.

d. Category 4 involves measures where the baseline and future systems have data that are not statistically equivalent, and the systems are operationally different.

Traditional descriptive and inferential statistics determine statistical equivalency. A preliminary approach to the use of these statistics is as follows.

a. Compute descriptive statistics making general comparisons of means, standard deviations, and trends.

b. Derive inferential statistics such as using ANOVA with post hoc testing to compare the baseline and future systems on a given measure. ANOVAs will be two-way tests comprised of

   1. systems (i.e., ARTS IIIA baseline versus the future system), and

   2. a second factor consisting of one of the following:

      a) four sectors,

      b) two runway configurations, or

      c) 15-min segments.

The ANOVA first checks for a difference in each of the factors and then for an interaction between the two factors. If the ANOVA reveals statistically significant differences, researchers should use post hoc testing to identify where the difference(s) occur.

Researchers should adopt an alpha level (or margin for error) based upon an operational projection of the power of the test. They should assume that ATC measures are normally distributed, permitting the use of parametric statistics. Non-parametric statistics may be appropriate for other measures. Statistical tests can be used as a technique to compare systems, but they do not eliminate the need for a controller caucus.

An example demonstrating the use of an ANOVA is to consider the baseline measure of the average workload for the terminal controller. Table 1 contains the means for this measure across the four sectors in the 27/22L runway configuration and shows these means and hypothetical means for a future system. Figure 2 depicts these means.

Table 1. Average Workload Rating by System

	Initial Dep.	South	Rockport	Final One
ARTS IIIA	3.0	2.9	3.7	3.7
Future System (hypothetical)	4.5	4.5	3.0	3.2

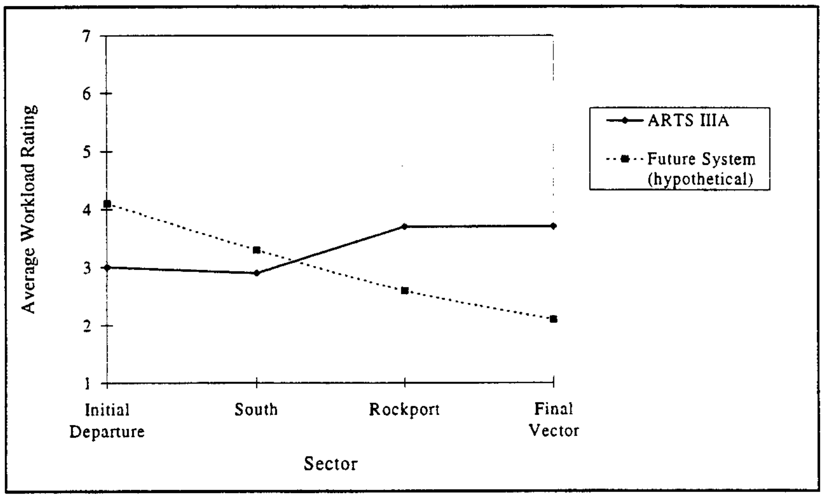

Figure 2. Average workload rating by sector for each system.

The ANOVA tests for an overall difference between the ARTS IIIA and a future system and for differences between sectors. It also tests the statistical significance of the interaction represented in Figure 2. The presence of an interaction means that there is a differential effect in how a measure such as workload changes across the two variables (systems and sectors). If the ANOVA shows significant overall effects or a significant interaction, the researcher conducts post hoc tests to determine where the difference(s) occur. This might show that the hypothetical future system has significantly lower workload than the ARTS IIIA for the arrival sectors. Even though the future system might show somewhat higher workload values for the departure sectors, the difference may not reach statistical or operational significance. Computational techniques for ANOVAs are readily available in statistics books and commercial software programs.

4.1.1 Refinements to the Baselining Methodology

For future efforts, researchers should consider the following enhancements to the baseline data extraction and analysis process. An important baseline measure for capacity is aircraft fuel consumption. This is an indicator of sector efficiency and could be based upon sector boundary crossing time in contrast to track control time. Fuel consumption could be measured according to average pounds of fuel consumed for all aircraft, by sector. Models would need the capability to handle TGF or CDR output. Researchers should also collect data for the ARTS IIIA performance time of functions or keyboard entries to assist in the evaluation of differences between the ARTS IIIA CHI and that of a future system.

During the preparation of this report, researchers identified the need for additional automated tools to expedite data reduction and analysis. These tools would be used offline beginning after completion of the first simulation runs and in parallel during the remaining simulation runs. In this manner, data could be presented in a timely and precise manner shortly after conclusion of the last simulation run. A particular problem was the extraction and analysis of CDR output. Further terminal baseline efforts would be more effective if improvements were made in the techniques available for working with these data.

4.1.2 Limitations and Constraints

The purpose of these data is to provide a baseline for future system comparisons with the ARTS IIIA. Neither the data nor the constructs upon which they are based should be considered as properly validated measures for use in other studies of controller or system performance. Further research is needed before the measures described in this report could be used for applications other than terminal system baselining.

CDR was not fully reliable during the simulation runs. Of the 24 successful runs, only 15 contained complete CDR output. Chi-square analyses were conducted to determine whether proportions of data in this smaller set were biased toward a particular runway configuration or data collection week. The 15 runs of CDR output are as representative of the two runway configurations as the full 24 runs of questionnaire, ATWIT, and TGF data, $\chi^2(1, N = 15) = 0.21$, $p > .05$. Table 2 shows the percentage of each runway configuration for the full and CDR data sets. The 15 runs of CDR output are as representative of the 3 weeks as the full data set, $\chi^2(2, N = 15) = 1.30, p > .05$. Table 3 shows the percentage of each week for the full and CDR data sets.

Table 2. Representativeness of Data Sets for Each Runway Configuration

	Percentage of Full Data Set	**Percentage of CDR Data Set**
27/22L Runway Configuration	46 %	40 %
4R/L Runway Configuration	54 %	60 %

Table 3. Representativeness of Data Sets for Each Week

	Percentage of Full Data Set	**Percentage of CDR Data Set**
Week 1	29 %	20 %
Week 2	38 %	33 %
Week 3	33 %	47 %

As a result, for conflict alert and keyboard entry data, the reported means and standard deviations are based on 15 completed runs rather than the full 24. This smaller sample probably resulted in increased variance for these variables. Efforts should be made in future ARTS IIIA baseline work to ensure more reliable performance.

Though this simulation attempted the highest fidelity available, there are areas in which it differed from the actual Boston TRACON, as follows:

a. At the Boston TRACON, the controller working the Departure Sector has a closed-circuit television display showing the flight strips of the tower controller. The controller then

knows the call signs of departure aircraft before the aircraft arrives in the terminal airspace. This simulation did not have this capability.

b. Technical limitations and limits on the training of the SIMOPs prevented the inclusion of VFR traffic. For simulated VFR traffic to move realistically through the airspace, SIMOPs would have needed far more training and knowledge of the terminal area and typical VFR flight plans than were available. The Boston TRACON would typically handle several VFR aircraft during a 90-min period on a 90th percentile day. It is possible that absolute measures (e.g., average workload and total data entries) are lower because fewer aircraft were present in the simulated airspace than would be present in the actual airspace. However, the measures reported per aircraft should be mostly unaffected by the lack of VFR traffic.

c. The staffing used in the simulation (i.e., four controllers with one supervisor) was lighter than a typical 90th percentile day when six controllers staff the positions. However, the exclusion of VFR and satellite traffic from the simulation scenarios made the staffing appropriate for the traffic load.

These limitations do not affect the validity of the data set. However, when making comparisons with future systems, researchers should maintain similar conditions.

5. Conclusions

This baseline study provides a data set that should be useful for ensuring that new ATC systems function as well or better than the existing ARTS IIIA. These data are critical as a foundation for making evaluations that would otherwise be based entirely on subjective judgment. If used as advised in this report, these data will provide a powerful tool for making system comparisons.

References

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Appendix A

Questionnaires and Forms

POST-SCENARIO QUESTIONNAIRE

Controller ID: a b c d   Date ________   Run ________
Position/Sector: South Init. Departure Rockport Final Vector
Test System: ARTS IIIA / ARTS IIIE / STARS

Instructions

The purpose of this questionnaire is to obtain information concerning different aspects of the air traffic control problem just completed. This information will be used to determine how the simulation experience affects your opinions. As you answer each question, feel free to use the entire numerical scale. Please be as honest and as accurate as you can. So that your identity can remain anonymous, your actual name should not be written on this form. Instead, your data will be identified by a controller code known only to yourself and the experimenters.

---

1) How well did you control traffic during this problem?

1	2	3	4	5	6	7	8
Not Very Well							Extremely Well

2) What was your average workload level during this problem?

1	2	3	4	5	6	7	8
Very Low Workload							Very High Workload

3) How difficult was this problem compared to other simulation training problems?

1	2	3	4	5	6	7	8
Not Very Difficult							Extremely Difficult

4) How good do you think your air traffic control services were from a pilot's point of view?

1	2	3	4	5	6	7	8
Not Very Good							Extremely Good

5) To what extent did technical problems with the simulation equipment interfere with your ability to control traffic?

1	2	3	4	5	6	7	8
Not Very Much							A Great Deal

6) To what extent did problems with simulator pilots interfere with your normal air traffic control activities?

1	2	3	4	5	6	7	8
Not Very Much							A Great Deal

7) How realistic was this simulation problem compared to actual air traffic control?

1	2	3	4	5	6	7	8
Not Very Realistic							Extremely Realistic

FINAL QUESTIONNAIRE

Controller ID: a b c d   Date ________

Test System: ARTS IIIA / ARTS IIIE / STARS

Section A

Please circle the number that best describes your level of agreement with each of the following statements concerning the current ARTS IIIA console.

1) The switches, knobs, and buttons on the console are easy to access.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

2) The operation and functions of the switches, knobs, and buttons on the console are intuitive.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

3) The controller keyboard is easy to use.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

4) The radar and map displays are easy to read.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

5) The radar and map displays are easy to understand.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

6) There is plenty of space to work within the workstation.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

7) The equipment, displays, and controls allow me to control traffic in the most efficient way possible.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

8) The equipment, displays, and controls allow me to control traffic without any awkward limitations.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

9) Overall, the equipment, displays, and controls are effective in meeting the needs of controllers.

1	2	3	4	5	6	7	8
Strongly Disagree							Strongly Agree

FINAL QUESTIONNAIRE
(continued)

Section B

Please circle the number that best describes your overall interaction with the equipment, displays, and controls (i.e., human-computer interface) of the ARTS IIIA console. In making these judgments, please consider your total experience with the ARTS IIIA, not just your experience during this simulation study.

Regarding my everyday air traffic control tasks, the ARTS IIIA system is:

1)	1 Not Very Limiting	2	3	4	5	6	7	8 Extremely Limiting
2)	1 Not Very Frustrating	2	3	4	5	6	7	8 Extremely Frustrating
3)	1 Not Very Effective	2	3	4	5	6	7	8 Extremely Effective
4)	1 Not Very Efficient	2	3	4	5	6	7	8 Extremely Efficient
5)	1 Not Very Easy to Operate	2	3	4	5	6	7	8 Extremely Easy to Operate
6)	1 Not Very Easy to Understand	2	3	4	5	6	7	8 Extremely Easy to Understand

FINAL QUESTIONNAIRE
(continued)

Section C

Please circle the number that best represents your opinion about the following potential improvements to the ARTS IIIA.

1) To what extent do you think a "windows" interface similar to that of personal computers would improve your effectiveness with the ARTS IIIA console?

❑ If you are not familiar with the "windows" interface, mark this box.

1	2	3	4	5	6	7	8
Not Very Much							A Great Deal

2) To what extent do you think a mouse input device (instead of a trackball) would improve your effectiveness with the ARTS IIIA console?

❑ If you are not familiar with a mouse input device, mark this box.

1	2	3	4	5	6	7	8
Not Very Much							A Great Deal

3) To what extent do you think color displays would improve your effectiveness with the ARTS IIIA console?

1	2	3	4	5	6	7	8
Not Very Much							A Great Deal

4) To what extent do you think a brighter lighting level would improve your effectiveness with the ARTS IIIA console?

1	2	3	4	5	6	7	8
Not Very Much							A Great Deal

FINAL QUESTIONNAIRE
(continued)

Section D

For each the following questions, indicate your opinion by marking one or more of the provided boxes. Then, please provide any additional comments that you think are appropriate.

1) Which aspects of the ARTS IIIA console need improvement?

- ❑ Radar and Map Displays
- ❑ Volume of Workspace
- ❑ Keyboard
- ❑ Other (specify) ________________
- ❑ Console Switches and Knobs
- ❑ Trackball
- ❑ Other (specify) ________________

Please provide some details about why you think each of these aspects needs improvement?

____
____
____
____
____
____
____
____

2) What are the most common mistakes you encounter using the ARTS IIIA console?

- ❑ Misreading Radar Display Information
- ❑ Misreading Map Display Information
- ❑ Making Entries with Keyboard
- ❑ Other (specify) ________________
- ❑ Selecting Targets with Trackball
- ❑ Adjusting the Correct Switch or Knob
- ❑ Other (specify) ________________

Please provide some details about what you think causes you to make each of these mistakes?

____
____
____
____
____
____
____
____

FINAL QUESTIONNAIRE
(continued)

Section E

If there are any other comments or suggestions that you have regarding this baseline study of the ARTS IIIA console, please write your ideas in the space provided below.

OBSERVER EVALUATION FORM

Observer Code ________ Date ________

Controller: a b c d

Position/Sector: South Init. Depart Rockport Final Vector

Simulation ________________

INSTRUCTIONS

This form was designed to be used by instructor certified air traffic control specialists to evaluate the effectiveness of controllers working in simulation environments. Observers will rate the effectiveness of controllers in several different performance areas using the scale shown below. When making your ratings, please try to use the entire scale range as much as possible. You are encouraged to write down observations, and you may make preliminary ratings during the scenario. However, we recommend that you wait until the scenario is finished before making your final ratings. The observations you make do not need to be restricted to the performance areas covered in this form and may include other areas that you think are important. Also, please write down any comments that may improve this evaluation form. Your identity will remain anonymous, so do not write your name on the form. Instead, your data will be identified by an observer code known only to yourself and the researchers conducting this study.

Rating	Label Description
1	Controller demonstrated *extremely* poor judgment in making control decisions and *very* frequently made errors
2	Controller demonstrated poor judgment in making some control decisions and occasionally made errors
3	Controller made questionable control decisions using poor control techniques which led to restricting the normal traffic flow
4	Controller demonstrated the ability to keep aircraft separated but used spacing and separation criteria which was excessive
5	Controller demonstrated *adequate* judgment in making control decisions
6	Controller demonstrated *good* judgment in making control decisions using efficient control techniques
7	Controller *frequently* demonstrated *excellent* judgment in making control decisions using extremely good control techniques
8	Controller *always* demonstrated excellent judgment in making even the most difficult control decisions while using outstanding control techniques
NA	**Not Applicable** - There was not an opportunity to observe performance in this particular area during the simulation

MAINTAINING SAFE AND EFFICIENT TRAFFIC FLOW

1. **Maintaining Separation and Resolving Potential Conflicts**	1	2	3	4	5	6	7	8	NA
- using control instructions that maintain safe aircraft separation - detecting and resolving impending conflicts early									
2. **Sequencing Arrival and Departure Aircraft Efficiently**	1	2	3	4	5	6	7	8	NA
- using efficient and orderly spacing techniques for arrival and departure aircraft - maintaining safe arrival and departure intervals that minimize delays									
3. **Using Control Instructions Effectively**	1	2	3	4	5	6	7	8	NA
- providing accurate navigational assistance to pilots - avoiding clearances that result in the need for additional instructions to handle aircraft completely - avoiding excessive vectoring or over-controlling									
4. **Overall Safe and Efficient Traffic Flow Scale Rating**	1	2	3	4	5	6	7	8	NA

MAINTAINING ATTENTION AND SITUATION AWARENESS

5. **Maintaining Awareness of Aircraft Positions**	1	2	3	4	5	6	7	8	NA
- avoiding fixation on one area of the radar scope when other areas need attention - using scanning patterns that monitor all aircraft on the radar scope									
6. **Ensuring Positive Control**	1	2	3	4	5	6	7	8	NA
7. **Detecting Pilot Deviations From Control Instructions**	1	2	3	4	5	6	7	8	NA
- ensuring that pilots follow assigned clearances correctly - correcting pilot deviations in a timely manner									
8. **Correcting Own Errors in a Timely Manner**	1	2	3	4	5	6	7	8	NA
9. **Overall Attention and Situation Awareness Scale Rating**	1	2	3	4	5	6	7	8	NA

PRIORITIZING

10. **Taking Actions in an Appropriate Order of Importance**	1	2	3	4	5	6	7	8	NA
- resolving situations that need immediate attention before handling low priority tasks - issuing control instructions in a prioritized, structured, and timely manner									
11. **Preplanning Control Actions**	1	2	3	4	5	6	7	8	NA
- scanning adjacent sectors to plan for inbound traffic - studying pending flight strips in bay									
12. **Handling Control Tasks for Several Aircraft**	1	2	3	4	5	6	7	8	NA
- shifting control tasks between several aircraft when necessary - avoiding delays in communications while thinking or planning control actions									
13. **Marking Flight Strips While Performing Other Tasks**	1	2	3	4	5	6	7	8	NA
- marking flight strips accurately while talking or performing other tasks - keeping flight strips current									
14. **Overall Prioritizing Scale Rating**	1	2	3	4	5	6	7	8	NA

PROVIDING CONTROL INFORMATION

15. Providing Essential Air Traffic Control Information	1	2	3	4	5	6	7	8	NA
- providing mandatory services and advisories to pilots in a timely manner - exchanging essential information									
16. Providing Additional Air Traffic Control Information	1	2	3	4	5	6	7	8	NA
- providing additional services when workload is not a factor - exchanging additional information									
17. Overall Providing Control Information Scale Rating	1	2	3	4	5	6	7	8	NA

TECHNICAL KNOWLEDGE

18. Showing Knowledge of LOAs and SOPs	1	2	3	4	5	6	7	8	NA
- controlling traffic as depicted in current LOAs and SOPs - performing handoff procedures correctly									
19. Showing Knowledge of Aircraft Capabilities and Limitations	1	2	3	4	5	6	7	8	NA
- avoiding clearances that are beyond aircraft performance parameters - recognizing the need for speed restrictions and wake turbulence separation									
20. Overall Technical Knowledge Scale Rating	1	2	3	4	5	6	7	8	NA

COMMUNICATING

21. Using Proper Phraseology	1	2	3	4	5	6	7	8	NA
- using words and phrases specified in ATP 7110.65 - using ATP phraseology that is appropriate for the situation - avoiding the use of excessive verbiage									
22. Communicating Clearly and Efficiently	1	2	3	4	5	6	7	8	NA
- speaking at the proper volume and rate for pilots to understand - speaking fluently while scanning or performing other tasks - clearance delivery is complete, correct and timely - providing complete information in each clearance									
23. Listening to Pilot Readbacks and Requests	1	2	3	4	5	6	7	8	NA
- correcting pilot readback errors - acknowledging pilot or other controller requests promptly - processing requests correctly in a timely manner									
24. Overall Communicating Scale Rating	1	2	3	4	5	6	7	8	NA

MAINTAINING SAFE AND EFFICIENT TRAFFIC FLOW

1. **Maintaining Separation and Resolving Potential Conflicts**

2. **Sequencing Arrival and Departure Aircraft Efficiently**

3. **Using Control Instructions Effectively**

4. **Other Actions Observed in Safe and Efficient Traffic Flow**

MAINTAINING ATTENTION AND SITUATION AWARENESS

5. **Maintaining Awareness of Aircraft Positions**

6. **Ensuring Positive Control**

7. **Detecting Pilot Deviations From Control Instructions**

8. **Correcting Own Errors in a Timely Manner**

9. **Other Actions Observed in Attention and Situation Awareness**

PRIORITIZING

10. Taking Actions in an Appropriate Order of Importance

11. Preplanning Control Actions

12. Handling Control Tasks for Several Aircraft

13. Marking Flight Strips While Performing Other Tasks

14. Other Actions Observed in Prioritizing

PROVIDING CONTROL INFORMATION

15. Providing Essential Air Traffic Control Information

16. Providing Additional Air Traffic Control Information

17. Other Actions Observed in Providing Control Information

TECHNICAL KNOWLEDGE

18. Showing Knowledge of LOAs and SOPs

19. Showing Knowledge of Aircraft Capabilities and Limitations

20. Other Actions Observed in Technical Knowledge

COMMUNICATING

21. Using Proper Phraseology

22. Communicating Clearly and Efficiently

23. Listening to Pilot Readbacks and Requests

24. Other Actions Observed in Communicating

ARTS Baseline Test
Observer Log

Observer Initials: ______________ Date: ____________ Run: ____________

Position/Sector: South Init. Departure Rockport Final Vector

Instructions: Please note the occurrence of missed approaches and missed ILS acquisitions by noting system time, the nature of the event, and the aircraft involved. Please also note any technical problems and other safety-critical or otherwise important events. Use back of page for explanations, if necessary.

System Time	Event	Aircraft

Appendix B

Briefing Document

Boston TRACON - Logan Airport

Terminal Baseline

Simulation Training Package

1.0 INTRODUCTION

The intent of this training package is to provide air traffic controllers with a working knowledge of the selected Boston TRACON airspace that will be employed during the Terminal Baseline Evaluation using the ARTS IIIA. The testing of the ARTS IIIA will not be an evaluation of controllers' skills. These simulations are part of an ongoing effort to assess operational suitability issues related to future air traffic control (ATC) systems.

These simulations have been designed to enable the controller to enter as many inputs into the system as possible. The intent is to provide "real world" situations. Included in this package are general descriptions of the Boston TRACON sectors/positions as well as procedures specific to each position that will be used in these simulations.

2.0 SIMULATION ENVIRONMENT

The Target Generation Facility (TGF) consists of four areas: Target Generator, Simulation Operation Pilots (SIMOPs), Exercise Control, and Development and Support. The TGF interfaces with National Airspace System (NAS) automation. The function of the TGF is to create a realistic ATC environment. Aircraft targets will respond to your instructions without question. Each time you call an aircraft, it should respond realistically.

The basic design of the system is to provide the user with a system that allows the controller to issue air traffic instructions. It should also have each aircraft perform in a manner similar to a real environment.

2.1 TARGET GENERATION FACILITY

The TGF is interfaced with the ARTS IIIA and Host systems and is designed to generate digital radar messages for a simulated airspace environment.

2.2 Simulation Pilots

The SIMOPs control the aircraft target during the simulation.

2.3 Exercise Control

The Exercise Control manages the execution of the exercise.

2.4 Development and Support

The Development and Support area includes the workstations that are used by the scenario development analyst to develop scenarios, validate the data base, and preview the scenario.

2.5 DOs and DON'Ts of the System

Do not expect the system to respond to you as an aircraft that has a pilot sitting at the controls. This means that your clearances must be technically correct in format.

Do not expect logical answers to questions that are outside the actual realm of control of the aircraft to which your SIMOP is responding. The SIMOPs have no visual reference to the movement of any aircraft in the sector. They do have access to much of the information you will need in the normal routine of controlling the aircraft involved (i.e., indicated airspeed, altitude information, heading, and distance for certain fixes along their filed route). They also can supply you with aircraft type, equipment, beacon code, and destination. Before the first simulation run begins, it is suggested that you brief your SIMOPs on typical instructions and clearances you will be using.

2.6 Support

There is a group of developers that work very hard to provide you with the best possible system. There is a constant stream of enhancements that they continue to work on throughout the year. When you leave this facility, we hope to have your ideas and suggestions to further improve the system.

Another group that continues to train each day to improve for you is the SIMOPs. Your relationship with the SIMOP is very important to them and the success of the scenarios we test. There are, however, a few things of which you should be aware. Although the training required of a SIMOP represents a sincere effort to provide you with realism, they are not professionally trained air traffic controllers and most of them have no pilot experience.

2.7 Ghost Positions

All the airspace included within any facility's area must be accounted for in a given simulation that is conducted here in the Technical Center Lab. This means that all relevant sectors must be included.

There are two additional sectors that must be used in the simulation and staffed by controllers. They are designated as "ghost positions." One sector is used to start the target (inbound ghost) and the other is used to terminate the target (outbound ghost).

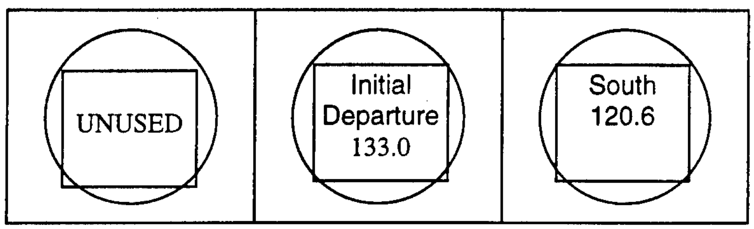
En route flights initially entering the facility's airspace are "started" (start track) in the simulation at a programmed time. Flights that originate inbound to the scenario are started (departed) from the inbound ghost sector. Flights that are terminated within the facility's airspace are terminated (drop track) in the outbound ghost sector's airspace.

When a flight is assigned one of the following termination frequencies, the SIMOP enters the frequency into the TGF computer, and the radar track then terminates, following 6 additional minutes of flight. The following frequencies can be used to terminate an aircraft when it exits a scenario sector into no-scenario airspace (adjacent facility/sector). When the aircraft is issued the appropriate frequency by the controller, the SIMOP will enter the frequency into the TGF computer. The frequencies are as follows:

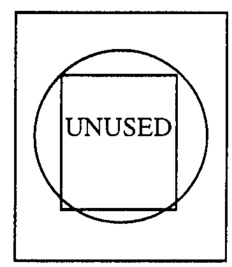
Boston Center-	133.42	128.75	134.7	128.2
Providence Approach-	133.85	135.4		
Bradley Approach-	123.95			
Cape Approach-	118.2			
Manchester Approach-	118.8	134.75	124.9	

3.0 SIMULATION SCENARIO DESCRIPTIONS

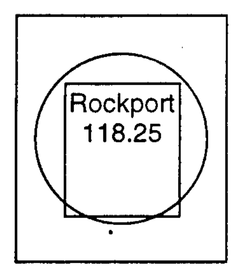
Boston TRACON will execute a developed scenario utilizing four radar positions. The level of traffic/complexity is mixed, and mostly moderate to heavy. Scenario duration is approximately 1.5 hours. The following diagram identifies the positions and associated frequencies:



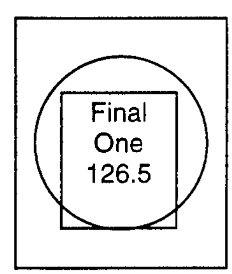
General Information



Radar Displays- The following RADAR displays are used in these scenarios:
Display #6=Initial Departure Position
Display #7=South Position
Display #9=Rockport Position
Display #10=Final One Position



Initial Departure
a. "D" position, frequency 133.0.
b. this position utilizes the position symbol "D".
c. combined with Lincoln Sector ("L").
d. all Boston Departures initiates at this position.
e. all arrivals from "WOONS" are handed off via interfacility to this position.



South Sector
a. "S" position, frequency 120.6.
b. combined with Plymouth Sector ("M").
c. this position utilizes position symbol "S" .
d. this position accepts handoffs from "D" destined to SID departure points of "FRILL," "BURDY," "SEY," "ACK," "HYA," "PVC," "LUCOS," "MVY," and "DRUNK."

e. this position will accept handoffs from interfacility arrival points of "PVC," "FREDO," and "PVD."

Rockport Sector

a. "R" position, frequency 118.25.
b. this position utilizes the position symbol "R."
c. this position accepts handoffs from "D" destined to SID departure points of "MHT" and "PSM."
d. this position accepts handoffs from interfacility arrival points of "GDM," "KHRIS," "RAYMY," and "SCUPP."

Final One

a. "F" position, frequency 126.5.
b. this position utilizes a position symbol "F."
c. this position accepts only intrafacility handoffs.

3.1 Initial Departure ("D")

In these scenarios, this position is combined with the Lincoln sector. Lincoln sector is predominantly a westbound departure corridor and an inbound sector for arrivals flight planned over "WOONS."

Frequency Information

Primary frequency for this position is 133.0

Departure Procedures

Initial Departure is the outlet for all aircraft departing the Logan International Airport. Aircraft are vectored per a RADAR Standard Instrument Departure (Logan-Nine SID) procedure, which outlines departure instructions and noise abatement procedures as follows:

ALL jet aircraft

Runway 22R or 22L: Fly heading 140 degrees, climb and maintain 5,000'.
Runway 9: Fly runway heading, climb and maintain 5,000'.
Runway 4R: Fly runway heading until the BOS 4 DME, then turn right heading 090 degrees, climb and maintain 5,000'.

ALL prop aircraft

Fly assigned heading, climb and maintain 3,000'.

Arrival Procedures

Since the configuration of Initial Departure combines the functions of "Lincoln Sector," the following arrivals require service.

Route	***Altitude***
WOONS BOS	7,000'

Controller Actions

1. All arrival aircraft are handed off to the Final Vector ("F") position for sequencing and approach clearances.

3.2 South Plymouth ("S")

This position is combined with the Plymouth Sector. Plymouth Sector is predominantly a southbound departure corridor and an inbound sector for arrivals flight planned over "PVD," "FREDO," and "PVC."

Frequency Information

Primary frequency for this position is 120.6

Departure Procedures

Departures are handed off from Initial Departure to this sector for jet/prop traffic departing southbound.

To Boston Center

Jet departures are vectored outbound on a heading of 170-210 degrees.
Jet departures routed over ACK (Nantucket) are issued "direct ACK."
Props requesting at or above 12,000' are issued "maintain 12,000'" and vectored on a heading of 170-210 degrees.

To Providence Approach

Props requesting at or below 10,000' shall be vectored to join V268 North of INNDY.

To Cape Approach

Props landing HYA, MVY, ACK are sent via "direct" at 5,000', 7000', or 9,000'.
Props landing PVC are sent via "direct" at 3,000'.

Arrival Procedures

The following arrivals will require service by this sector/position landing Boston.

Runway	*Route*	*Altitude/Restriction(s)*
4R	PVD.V141.INNDY.BOS	cross PVD at 11,000', at 250 knots
27	PVD.V141.INNDY.BOS	cross PVD at 11,000', no speed restriction
27	FREDO.BOS	6,000'
27	PVC.BOS	4,000'

Controller Actions

1. Aircraft may be vectored to either 4R or 4L, as determined by controller personnel for a more efficient use of airspace/runway utilization.

2. All arrival aircraft are handed off to the Final Vector ("F") position for sequencing and approach clearances.

3.3 Rockport Sector ("R")

Rockport Sector is predominantly a north/northeast bound departure corridor and an inbound sector for arrivals flight planned over "GDM," "RAYMY," "KHRIS," and "SCUPP."

Frequency Information

Primary frequency for this position is 118.25

Departure Procedures

Departures are handed off from Initial Departure to this sector for jet/prop traffic departing north/northeast bound.

To Boston Center

Jet departures are vectored outbound "direct MHT" or "direct PSM," as appropriate.
Prop departures are vectored outbound "direct MHT" or "direct PSM," as appropriate.
Props requesting at or above 12,000' are issued "maintain 12,000'" and vectored "direct MHT" or "direct "PSM," as appropriate.

To Manchester Approach

Prop departures to Boston Center (at or above 12,000') may be issued "maintain 10,000'" and handed off to Manchester Approach. Five (5) mile longitudinal separation shall be provided to these successive operations.

All other aircraft will be issued "direct MHT" and climbed to 10,000' or lower, as requested.

Arrival Procedures

The following arrivals require service by this sector/position landing Boston.

Runway	*Route*	*Altitude/Restriction(s)*
all	RAYMY.LWM.BOS	6,000' (props)
all	KHRIS.LWM.BOS	5,000' (props)
all	GDM.V431.REVER.BOS	cross BRONC (props) 9,000'
all	GDM.V431.REVER.BOS	cross BRONC (jets) 11,000', at 250 knots
27	SCUPP.BOS	jets 11,000', at 230 knots
4R	SCUPP.BOS	jets 11,000', at 250 knots
all	SCUPP.BOS	props 10,000'

Controller Actions

1. Aircraft may be vectored to either 4R or 4L, as determined by controller personnel for a more efficient use of airspace/runway utilization.

2. Aircraft may be vectored to either 22L or 27, as determined by controller personnel for a more efficient use of airspace/runway utilization. In either case, ensure aircraft assigned runway 22L by controllers are capable of the hold short operation (simultaneously landing runway 27).

3. All arrival aircraft are handed off to the Final Vector ("F") position for sequencing and approach clearances.

3.4 Final One ("F")

In these scenarios, this position is combined with the Final Two-(I) position. Final One is the final approach control position where all approach clearances are issued for Logan International Airport and aircraft are subsequently transferred to the Tower Local Control for landing clearances. This position does not typically control departure traffic, though coordination for such operations may be requested.

Frequency Information

Primary frequency for this position is 126.5

Arrival Procedures

The following arrivals require service by this sector/position landing Boston.

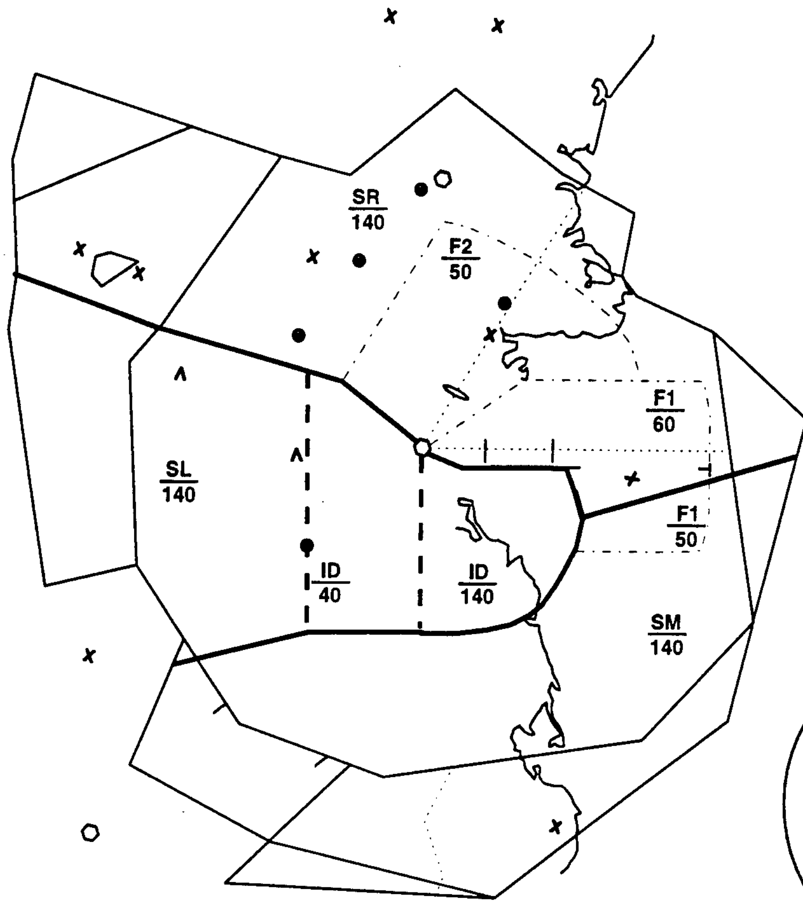
Runway	*Aircraft Type*	*Transferred By*	*Altitude/Route*
4R	jets	Rockport Sector	6,000'/on a right downwind
4R	jets	South/Plymouth Sector	6,000'/established on the extended use 4R localizer
4L	props	Rockport Sector	5,000'/on a left downwind
4L	props	Init. Departure from WOONS	4,000'/direct BOS VOR
27/22L	jets/props	Rockport Sector from GDM	6,000'/on a right downwind
27	jets	Rockport Sector from SCUPP	6,000'/vector to join the runway 27 localizer
27	props	Rockport Sector from SCUPP	5,000'/vector to join the runway 27 localizer
27	jets	South/Plymouth	5,000'/left base leg vector at TONNI
27	props	South/Plymouth	4,000'/left base leg vector at TONNI
22L	props	Rockport Sector from RAYMY	4,000'/right base leg from LWM VOR
22L	props	Rockport Sector from KHRIS	4,000'/right base leg from LWM VOR
22L	props	Init. Departure from WOONS	5,000'/right downwind

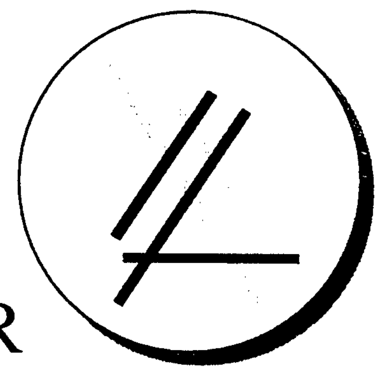
<u>Controller Actions</u>

1. Aircraft may be vectored to either 4R or 4L, as determined by controller personnel for a more efficient airspace/runway utilization. Aircraft inbound for Runway 4L should be vectored for the visual approach to an imaginary final. SIMOP personnel will make all descents and necessary turns after the issuance of the visual approach. Runway 4R, 22L, and 27 arrivals shall be vectored for that runway's published ILS approach.

2. Primary runway arrivals (runway 4R or 27, depending on configuration) shall remain on the position symbol "F." Secondary arrivals (runway 4L or 22L) data tags shall be changed (local ARTS patch) to a position symbol of "X." This identifies the runway assignment and reduces confusion by Approach/Tower personnel.

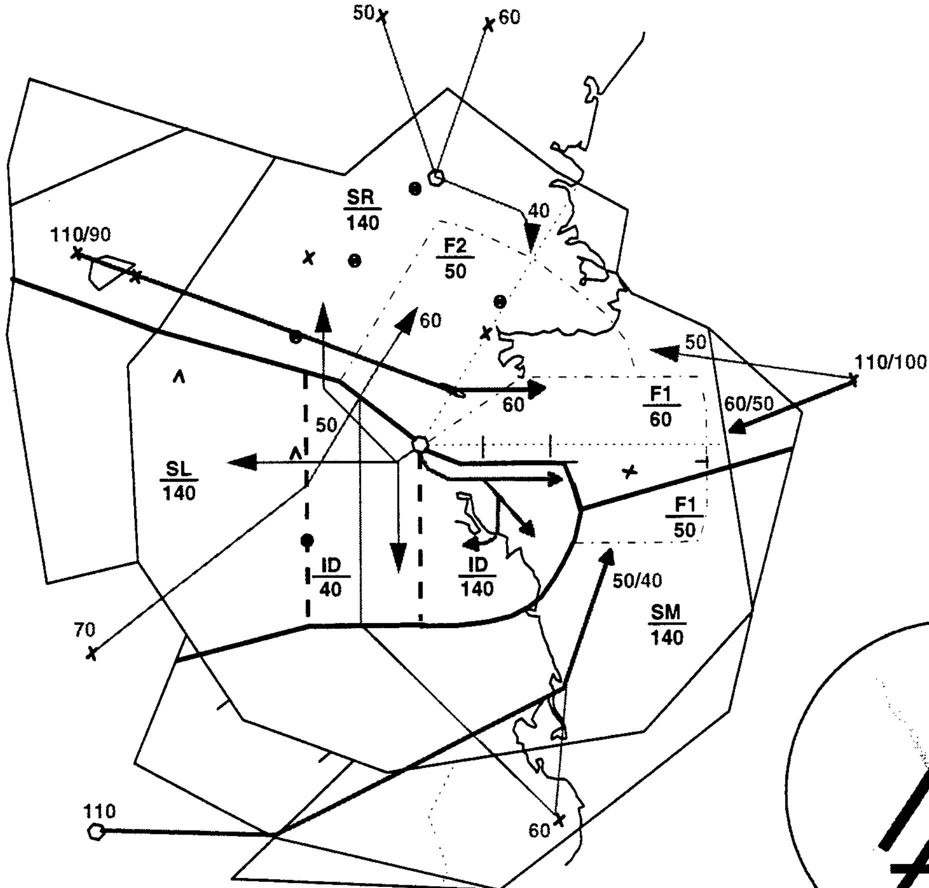
3.5 Airspace Descriptions

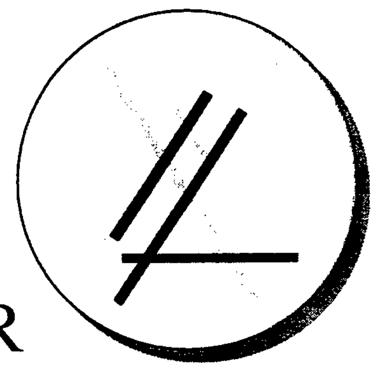




Land 27/22L, Depart 22R

A general outline of the overall airspace delegated to Boston TRACON incorporating internal sectorization for operations for the Land Runway 27/22L, Depart Runway 22R configuration.

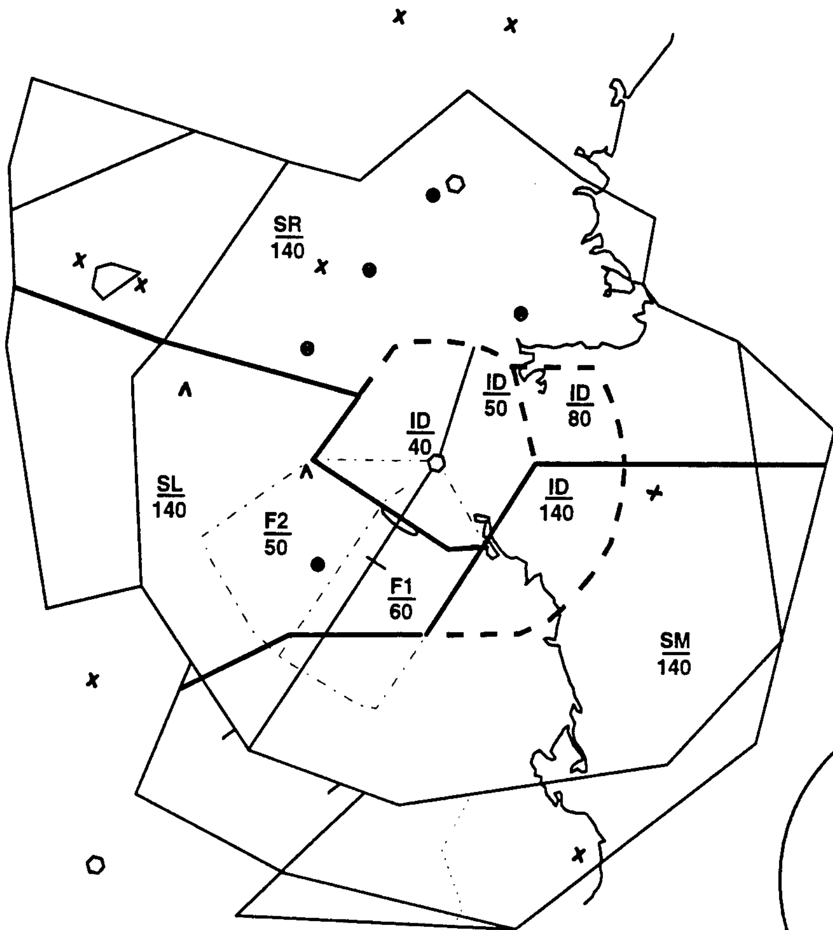




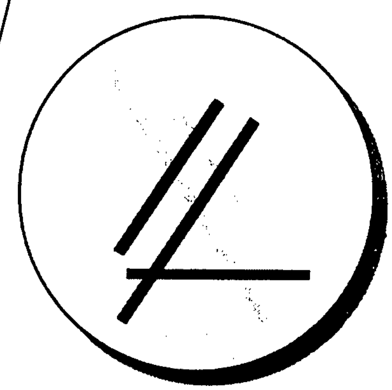
Land 27/22L, Depart 22R

A look at the overall flow of traffic for this configuration.

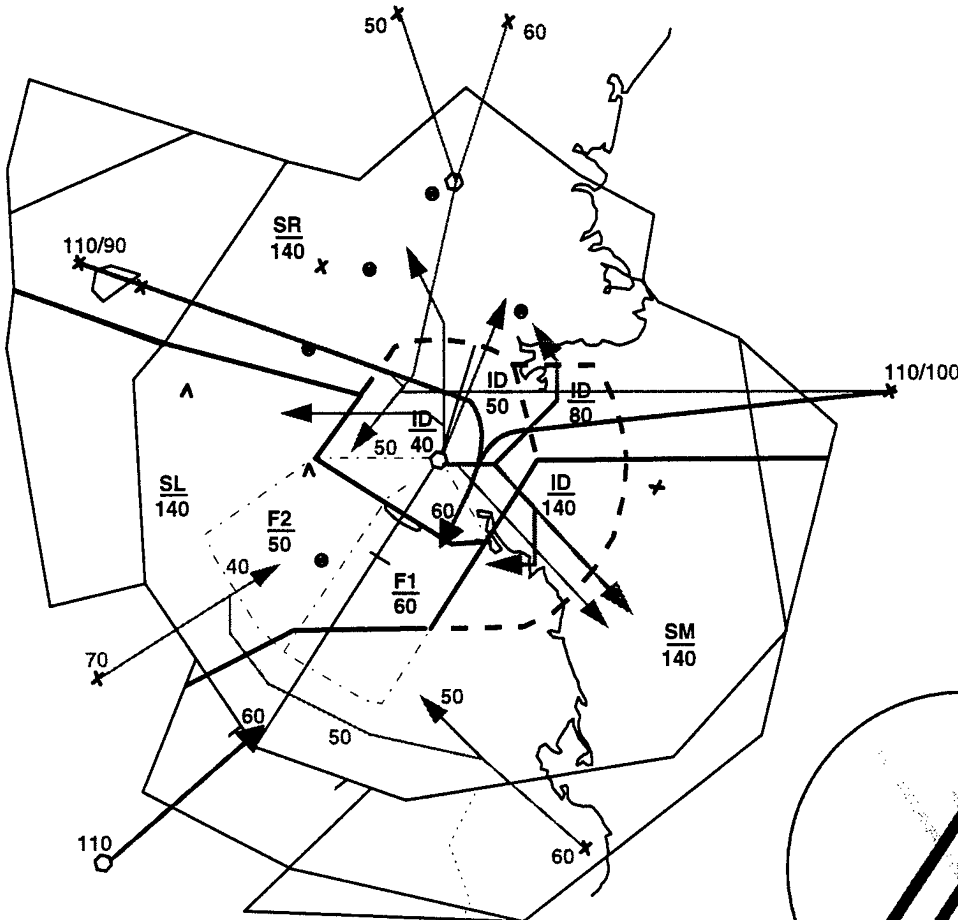
color key
red=JET arrival flow (thick line)
blue=JET departure flow (thick line)
orange=PROP arrival flow (thin line)
green=PROP departure flow (thin line)



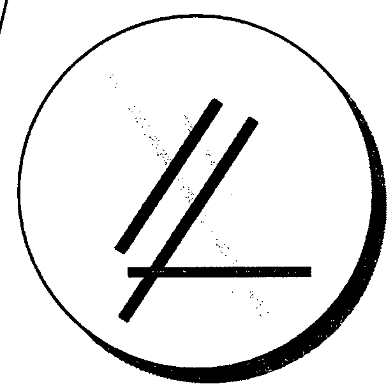
Land 4R/L, Depart 9



A general outline of the overall airspace delegated to Boston TRACON incorporating internal sectorization for operations for the Land Runway 4R/L, Depart Runway 9 configuration.



Land 4R/L, Depart 9



A look at the overall flow of traffic for this configuration.

color key
red=JET arrival flow (thick line)
blue=JET departure flow (thick line)
orange=PROP arrival flow (thin line)
green=PROP departure flow (thin line)

3.6 Additional Scenario Information

TI List

A list from the flight plan database is generated using a script developed by SRC personnel. See Stan Rimdzius or Nizam Taleb.

Arrival Handoff Positions/Times

Handoffs of arrival aircraft will begin approximately 30 seconds after target initiation, regardless of inbound Boston airspace sector involved.

Frequencies Used for Interfacility Handoffs and Termination

Boston Center (implied handoff by selecting the character "C" and slewing):

133.42-Bosox Sector-(Bosox, Glyde, Nelie at or above 11,000')
128.75-Cape Sector-(SEY, Lucos, ACK, HYA at or above 11,000')
134.7-Concord Sector-(MHT at or above 11,000)
128.2-Parso Sector-(PSM at or above 11,000', and all FRILL)

Providence Approach (implied handoff by selecting "delta 1" and slewing):

133.85-Providence East High/Low-(BURDY, V268, east satellites)
135.4-Providence West High/Low-(all west satellites)

Bradley Approach (implied handoff by selecting "delta 2" and slewing):

123.95-Bradley (Bosox, Glyde at or below 10,000')

Cape Approach (implied handoff by selecting "delta 3" and slewing):
118.2-Cape High/Low (HYA, MVY, ACK, PVC at or below 10,000')

Manchester Approach (implied handoff by selecting "delta 4" and slewing):

118.8-Manchester East (PSM at or below 10,000)
134.75-Manchester West (MHT 5,000' to 10,000')
124.9-Manchester South (landing MHT, ASH at below 4,000)

Target Termination

Target termination occurs 6 minutes after interfacility transfer of communications has occurred. This ensures that the aircraft departs Boston's airspace. Use of any of the above interfacility frequencies would indicate those aircraft requiring this action.

Voice Communication Equipment Layout

The following tables identify the position labeling for the voice communication equipment. The order of these labels should be consistent with the following tables to ensure controller familiarity. Foot switches should be incorporated at each operating position for optional use by controller personnel.

At Radar Display #6 -Initial Departure

2050	MHT2	MHTT	N	S	
2151	BDL	OQU	R	L	
2154	FMH	FV1	M	HELO	LS
2307	AM	FV2	LCW	LCE	RLS

At Radar Display #7 -South Position

5027	MHT2	MHTT	N	N*M	NZW
5028	BDL	OQU	R	L	OWD
2050	FMH	FV1	M	HELO	LS
2151	D	FV2	LCW	LCE	RLS

At Radar Display #9 -Rockport Sector

5028	MHT2	MHTT	N	S	
2150	BDL	OQU	AM	L	
2151	FMH	FV1	M	HELO	LS
2154	D	FV2	LCW	LCE	RLS

At Radar Display #10 -Final Vector

		D	N	S	
			R	L	
			M	HELO	LS
			LCW	LCE	RLS

Functionality

Buttons labeled D, S, R, and FV1 should have voice routed to those respective RADAR positions identified. These should serve as an override to radio frequency transmissions.

Buttons labeled L, M, FV2 serve a visual function in labeling only and are not routed to other positions/SIMOPs at this time.

All remaining buttons are routed to equipment, scheduled to be temporarily placed within the SIMOP area, for service as coordinated with ACT-510. These buttons MAY require controller personnel to use the push-to-talk feature of their headsets to enable conversation with that position/facility called up.

4.0 SIMULATION SCHEDULE

4.1 Week 1 Simulation Schedule and Work Assignments

4.1.1 Definitions

Simulation A Configuration: Land 27/22L, depart 22R
Simulation B Configuration: Land 4R/L, depart 9
Position 1 is Initial Departure
Position 2 is South (combined with Plymouth Sector)
Position 3 is Rockport Sector
Position 4 is Final Vector

4.1.2 Day 1

Pre-Briefing: 1400 - 1600

Laboratory Orientation: 1600 - 1800

4.1.3 Day 2

Meet in ARTS Lab: 1530

Simulation A1: 1630 - 1830

Position	***Controller***
1	A
2	B
3	C
4	D

Break: 1830 - 1930

Simulation B1: 1930 - 2100

Position	***Controller***
1	D
2	C
3	B
4	A

Simulation A2: 2130 - 2300

Position	***Controller***
1	B
2	C
3	D
4	A

4.1.4 Day 3

Meet in ARTS Lab: 1530

Simulation B2: 1630 - 1830

Position	*Controller*
1	A
2	D
3	B
4	C

Break: 1830 - 1930

Simulation A3: 1930 - 2100

Position	*Controller*
1	C
2	D
3	A
4	B

Simulation B3: 2130 - 2300

Position	*Controller*
1	B
2	A
3	D
4	C

4.1.5 Day 4

Meet in ARTS Lab: 1530

Simulation A4: 1630 - 1830

Position	*Controller*
1	D
2	A
3	B
4	C

Break: 1830 - 1930

Simulation B4: 1930 - 2100

Position	*Controller*
1	C
2	B
3	A
4	D

Debriefing: 2130 - 2300

4.2 Week 2 Simulation Schedule and Work Assignments

4.2.1 Definitions

Simulation A Configuration: Land 27/22L, Depart 22R
Simulation B Configuration: Land 4R/L, Depart 9
Position 1 is Initial Departure
Position 2 is South (combined with Plymouth Sector)
Position 3 is Rockport Sector
Position 4 is Final Vector

4.2.2 Day 1

Pre-Briefing: 1400 - 1600

Laboratory Orientation: 1600 - 1800

4.2.3 Day 2

Meet in ARTS Lab: 1530

Simulation B1: 1630 - 1830

Position	*Controller*
1	A
2	B
3	C
4	D

Break: 1830 - 1930

Simulation A1: 1930 - 2100

Position	*Controller*
1	D
2	C
3	B
4	A

Simulation B2: 2130 - 2300

Position	*Controller*
1	B
2	C
3	D
4	A

4.2.4 Day 3

Meet in ARTS Lab: 1530

Simulation A2: 1630 - 1830

Position	*Controller*
1	A
2	D
3	B
4	C

Break: 1830 - 1930

Simulation B3: 1930 - 2100

Position	*Controller*
1	C
2	D
3	A
4	B

Simulation A3: 2130 - 2300

Position	*Controller*
1	B
2	A
3	D
4	C

4.2.5 Day 4

Meet in ARTS Lab: 1530

Simulation B4: 1630 - 1830

Position	*Controller*
1	D
2	A
3	B
4	C

Break: 1830 - 1930

Simulation A4: 1930 - 2100

Position	***Controller***
1	C
2	B
3	A
4	D

Debriefing: 2130 - 2300

4.3 Week 3 Simulation Schedule and Work Assignments

4.3.1 Definitions

Simulation A Configuration: Land 27/22L, Depart 22R
Simulation B Configuration: Land 4R/L, Depart 9
Position 1 is Initial Departure
Position 2 is South (combined with Plymouth Sector)
Position 3 is Rockport Sector
Position 4 is Final Vector

4.3.2 Day 1

Pre-Briefing: 1400 - 1600

Laboratory Orientation: 1600 - 1800

4.3.3 Day 2

Meet in ARTS Lab: 1530

Simulation A1: 1630 - 1830

Position	***Controller***
1	A
2	B
3	C
4	D

Break: 1830 - 1930

Simulation B1: 1930 - 2100

Position	*Controller*
1	D
2	C
3	B
4	A

Simulation A2: 2130 - 2300

Position	*Controller*
1	B
2	C
3	D
4	A

4.3.4 Day 3

Meet in ARTS Lab: 1530

Simulation B2: 1630 - 1830

Position	*Controller*
1	A
2	D
3	B
4	C

Break: 1830 - 1930

Simulation A3: 1930 - 2100

Position	*Controller*
1	C
2	D
3	A
4	B

Simulation B3: 2130 - 2300

Position	*Controller*
1	B
2	A
3	D
4	C

4.3.5 Day 4

Meet in ARTS Lab: 1530

Simulation A4: 1630 - 1830

Position	*Controller*
1	D
2	A
3	B
4	C

Break: 1830 - 1930

Simulation B4: 1930 - 2100

Position	*Controller*
1	C
2	B
3	A
4	D

Debriefing: 2130 - 2300

4.4 Data Collection

Several types of data will be collected to provide baseline information on the ARTS IIIA.

4.4.1 Computer-Recorded Data

Measures of such items as number of aircraft handled, frequency of conflict alerts, and number of communications will be collected by the TGF, ARTS IIIA, and Amecom (voice switching) systems. This data collection is automatic and requires no effort from the controllers.

4.4.2 Questionnaire Data

Your opinions on the usability of the ARTS IIIA will be requested, along with other types of information, using questionnaires. Please complete the Background Information Questionnaire found in section 5 of this briefing package. Other questionnaires will be distributed at the end of each run and at the end of the third day of simulation.

4.4.3 Expert Observer Data

Air traffic controllers from Boston TRACON and other locations will be observing the simulation runs and recording information on several topics. Among other things, they will be evaluating your performance on a number of scales developed by the Human Factors Laboratory. This is to assess how well the ARTS IIIA supports you in your work and as a basic check on

quality of performance. This information will remain confidential and will not be included in any report materials.

4.4.4 Workload Data

To determine the baseline characteristics of the ARTS IIIA, it will be very important to collect workload data. This will be accomplished using a workload estimating method called the Air Traffic Workload Input Technique. A keypad will be positioned at your workstation. Every 4 minutes, you will be prompted by auditory and visual signals to enter a number between 1 and 7 on the keypad. One will indicate lowest workload and 7 will indicate highest workload.

5.0 CONSENT FORM

5.1 Purpose

The FAA is currently in the process of procuring new terminal air traffic control systems (i.e., STARS). To evaluate the relative merits of these new systems, we are collecting baseline data for the current ARTS IIIA console. Later, similar data will be collected in studies of the future system. As you work the air traffic control problems in this simulation, data will be recorded regarding your workload, system capacity, and system performance. The purpose of these measures is not to evaluate individual controllers but to determine the effectiveness of the ARTS IIIA console. Also, you will be asked to complete several questionnaires requesting your opinions concerning the human-computer interface (i.e., workstation equipment, computer displays, and console switches and knobs) of the ARTS IIIA console.

5.2 Rights of Participants

Please understand that your participation in this study is strictly voluntary, and your right to privacy will be protected. Your responses will be identified by a participant code known only to yourself and the experimenters. No individual names or identities will be recorded or released in any reports. If you have any questions at any time regarding the study, the experimenters will be happy to answer them.

5.3 Video Recording of Experiment

Please be aware that we are making video recording of this baseline study for a comparison with future systems. If you strongly object to having yourself recorded as you participate in this simulation, please inform the experimenters immediately.

6.0 BACKGROUND QUESTIONNAIRE

Controller ID: a b c d   Date ________

Test System: ARTS IIIA / ARTS IIIE / STARS

Instructions

The purpose of this questionnaire is to obtain information concerning your experience and background. This information will be used to describe the participants in this study as a group. So that your identity can remain anonymous, your actual name should not be written on this form. Instead, your data will be identified by a controller code known only to yourself and the experimenters.

---

1) What is your age?
   _____ years

2) How many years have you actively controlled traffic?
   _____ years

3) How many years have you used the ARTS IIIA system?
   _____ years

4) How many of the past 12 months have you actively controlled traffic?
   _____ months

5) What is your current position as an air traffic controller?
   ❑ Developmental ❑ Full Performance Level ❑ Other (specify) __________

6) In which environment do you have the most experience as an air traffic controller?
   ❑ En Route ❑ Terminal ❑ Other (specify) __________

7) If you wear corrective lenses, will you have them with you to wear during the simulation?
   ❑ Yes ❑ No ❑ I don't wear corrective lenses

8) Circle the number which best describes your current state of health.

1	2	3	4	5	6	7	8
Not Very Healthy							Extremely Healthy

9) Circle the number which best describes your current skill as an air traffic controller.

1	2	3	4	5	6	7	8
Not Very Skilled							Extremely Skilled

10) Circle the number which best describes your level of experience with personal computers.

1	2	3	4	5	6	7	8
Not Very Experienced							Extremely Experienced

11) Circle the number which best describes your level of satisfaction with the ARTS IIIA.

1	2	3	4	5	6	7	8
Not Very Satisfied							Extremely Satisfied

Appendix C

Measure Summary and Sector Data

Table C-1. Measure Summary Table for All Constructs

Construct	Variable	Description	Rationale	ARTS IIIA Value	Comment
Safety	Operational Errors	Loss of applicable separation minima (per FAA Order 7210.3K).	Basic safety measure.	Total number:[1,2] 21	Data analysis information[3]. See Table C-2 for sector information
	Conflict Alerts	Host conflict prediction algorithm.	Warning of potential conflict.	Total number/run for all sectors:[4,5] 4.6	See Table C-2 for sector information.
	Other Safety-Critical Issues	Observations of system safety deficiencies.	Capture additional safety concerns not otherwise recorded.	Five safety critical issues	Data analysis information[6].
Capacity	Aircraft Under Control	Total number of aircraft under track control.	Basic capacity measure.	Total number of aircraft handled/run for all sectors: 533.7	See Table C-2 for sector information.
	Average Time in Airspace	Average minutes an aircraft spent in the airspace.	Basic capacity/ efficiency measure.	Average minutes: 10.6 (6.21)[7]	
	Average Arrival Time	Average minutes an arrival aircraft spent in the airspace.	Basic arrival capacity/efficiency measure.	Average minutes: 14.7 (5.43)	

[1] All data reported are for the full run time of each traffic scenario, 90 minutes. There were 24 runs in each of the 4 sectors for a total of 56 runs.

[2] A score of .5 was given for each aircraft showing an operational error.

[3] We initially derived the number of operational errors from TGF data recordings. These recordings listed the closest point of approach of all aircraft pairs that violated terminal airspace separation minima. However, this strict criterion for an operational error resulted in many false alarms (i.e., an operational error was counted for aircraft pairs that technically violated the separation minima but that would not be considered errors by an ATC professional). In order to eliminate these false alarms, we further reviewed each loss-of-separation incident to determine if the incident was a genuine operational error. We prepared videotape clips showing each incident. A Boston TRACON supervisor reviewed these clips and determined which incidents should be counted as operational errors and which should be eliminated as false alarms. Of the original set of 39 loss-of-separation incidents, we eliminated 18 as false alarms. Reasons for elimination included SIMOP errors that pilots would not normally make, visual separation clearances issued, and diverging courses.

[4] The term "for all sectors" indicates that the number reported was a sum of the results at the sector level (table 2).

[5] A score of .5 was given for each aircraft showing a conflict alert.

[6] Expert observers recorded problems that occurred during the runs, noting the time and aircraft involved. As part of the data analysis, a supervisor from Boston TRACON examined the lists of problems and identified which problems were due to the simulation environment (e.g., SIMOP software problems) and which problems could occur in the field (e.g., scatters). The problems found in the field fell into three categories: safety-related issues, workload-related issues, and nuisance issues. Observers recorded five safety-related issues during the simulation: scatters, aircraft in coast, missing data tags, frozen displays, and missing conflict alert messages. Observers recorded three workload-related issues: handoff problems, inappropriate flashing, and failed inter-facility communication. Observers recorded four nuisance issues: keyboard keys sticking, trackballs sticking, off-center map displays, and climbing aircraft showing low-altitude alerts. Because we identified these issues during and after the simulations, we developed no *a priori* techniques to measure these problems. As a result, it would be invalid to count the number of times observers recorded these problems as the frequency at which these problems occurred. Future studies should include techniques to measure the frequency of these problems.

[7] Values in parentheses show standard deviations.

Table C-1. Measure Summary Table for All Constructs (Cont.)

Construct	Variable	Description	Rationale	ARTS IIIA Value	Comment
Capacity	Average Departure Time	Average minutes a departure aircraft spent in the airspace.	Basic departure capacity efficiency measure.	Average minutes: 6.7 (3.97)	See Table C-2 for sector information.
	Average Spacing on Final Approach	Distance from aircraft over middle marker to trailing aircraft.	Measure of efficiency of arrival flow.	N/A[8]	
	Minutes between Landings	Minutes between consecutive aircraft passing over the middle marker.			
	Altitude Assignment Per Aircraft	Ratio of total altitude changes and number of aircraft.	Detects efficiency in moving flights through airspace.		
Performance	Data Entries	Total data entries and breakdown by category.	Measures effort required to make data entries into system.	Total entries/run for all sectors: 1308.9	See Table C-2 for sector information and Table C-6 for breakdown by categories.
	Data Entry Errors	Total data entry errors.	Detects data entry problems.	Total errors/run for all sectors: 35.1	See Table C-2 for sector information.
	Number of Altitude, Speed, and Heading Changes	Count of TGF pseudo-pilot entries to control aircraft (in response to controller instructions).	Indicates user interface effectiveness.	Total number/run for all sectors: 2191.6	
(Controller Questionnaire)	1. Quality of ATC Services (Pilot)	Measures of quality of service.	Indicates system usability.	Average rating:[9] 6.7 (1.15)	See Table C-4 for sector information
	2. Quality of ATC Services (Controller)			Average rating: 6.8 (1.12)	
(Expert Observer Questionnaire)	1. Maintain Safe/Efficient Flow	Measures of controller performance as evaluated by expert observers.	Indicates system efficiency/ effectiveness.	Average rating: 7.1 (0.83)	None
	2. Maintain Attention/Vigilance			Average rating: 7.4 (0.50)	
	3. Prioritizing			Average rating: 7.4 (0.51)	
	4. Communicate/Inform			Average rating: 7.1 (0.63)	
	5. Technical Knowledge			Average rating: 7.5 (0.65)	
Workload	Workload per Aircraft	Ratio of subjective workload (ATWIT) and number of aircraft tracked.	Detects changes in subjective workload to control aircraft.	N/A	See Table C-2 for sector information.

8 "Not Applicable" indicates that it was not appropriate to report an average or sum across sectors for this variable.

9 These values are average ratings made by the controllers on the post-run questionnaires. The ratings ranged from 1 (strongly disagree) to 8 (strongly agree).

Table C-1. Measure Summary Table for All Constructs (Cont.)

Construct	Variable	Description	Rationale	ARTS IIIA Value	Comment
Workload	Average Workload	Average ATWIT workload per run.	Detects changes in subjective workload to control aircraft.	N/A	See Table C-2 for sector information.
	Post-Run Workload	Subjective workload as measured by questionnaire at the end of each run.			
	Communication Workload	Ratio of total communications and number of aircraft.	Detects changes in communications needed to control aircraft.		
	Data Entry Workload	Ratio of total data entries and number of aircraft.			
Usability	1. Ease of Access of Controls	System Usability Measures.	Indicators of efficiency/ effectiveness of user interface.	Average rating: 5.9 (1.60)	None
	2. Operation of Controls Intuitive			Average rating: 4.5 (1.94)	
	3. Keyboard Ease of Use			Average rating: 4.9 (2.12)	
	4. Radar and Map Displays Ease of Reading			Average rating: 5.2 (1.63)	
	5. Radar and Maps Displays Ease of Understanding			Average rating: 5.8 (1.28)	
	6. Workstation Space			Average rating: 4.8 (1.92)	
	7. Equipment, Displays, and Controls Support Efficient ATC			Average rating: 4.1 (1.87)	
	8. Equipment, Displays, and Controls Impose Limitations			Average rating: 4.4 (1.88)	
	9. Equipment, Displays, and Controls Overall Effectiveness			Average rating: 4.8 (1.79)	
	10. Overall Quality of Interaction with Equipment			Average rating (over first 6 scales): 5.2 (1.86)	
Simulation Fidelity	1. Scenario Length	Minutes run each scenario.	Characterizes the simulation.	Minutes: 90	None
	2. Number of Arrivals	The number of aircraft of a particular type used in the simulation.	Characterizes the traffic used in the simulation.	No. of Aircraft: 79.7 (1.00)	See Table C-2 for sector information.
	3. Number of Departures			No. of Aircraft: 84.7 (2.20)	
	4. Number of En Route			No. of Aircraft: 0.0 (0.00)	
	5. Number of Jets			No. of Aircraft: 82.6 (2.32)	
	6. Number of Propellers			No. of Aircraft: 81.8 (0.85)	
	7. Realism	Perceived fidelity of simulation scenarios.	Check on realism of simulation.	Average rating: 5.0 (1.67)	
	8. Technical Problems			Average rating: 3.1 (2.03)	
	9. Problem Difficulty			Average rating: 4.2 (1.56)	None

Table C-2. Quantitative Sector Data: Means for Each Position in Each Configuration

		Runway Configuration 27/22L				Runway Configuration 4R/L				
Construct	Variable	D	S	R	F	D	S	R	F	Comment
Safety	Operational Errors	0.0	0.0	0.0	1.0	0.0	0.0	1.5	18.5	None
	Conflict Alerts	0.5	0.2	0.8	1.1	0.1	0.0	1.0	1.1	See Section 2.6 for discussion.
Capacity	Aircraft Under Control	89.4	50.5	64.1	65.2	88.1	51.6	60.7	64.2	See Tables C 9-24 for time interval data.
	Average Time in Airspace (min)	4.4	7.0	5.9	8.1	3.8	4.6	8.4	7.6	See Section 2.6 for discussion.
	Average Arrival Time	8.7	9.5	6.4	8.2	4.1	5.2	11.7	7.6	
	Average Departure Time	4.0	4.4	5.2	1.2	3.7	3.9	4.1	0.7	
	Altitude Assignments per Aircraft	1.2	1.3	1.3	2.1	1.2	0.8	1.4	2.9	See Tables C-9 to 24 for time interval data.
	Average Spacing on Final Approach (feet)	N/A	N/A	N/A	28,339	N/A	N/A	N/A	24,205	
	Minutes between landings	N/A	N/A	N/A	2.8	N/A	N/A	N/A	2.2	
Performance	Data Entries	211.7	158.0	219.0	121.0	203.3	126.2	172.8	96.9	See Tables C-9 to 24 for time interval data and Table C-4 for category breakdown
	Data Entry Errors	7.5	6.2	7.0	2.0	6.0	3.1	2.9	0.4	See Tables C-9 to 24 for time interval data.
	Number of Altitude, Speed, and Heading Changes	293.9	182.6	203.4	379.4	233.3	126.2	266.1	506.8	None
Workload	Workload per Aircraft	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.2	See Tables C-9 to 24 for time interval data.
	Average Workload	3.0	2.9	3.7	3.7	3.0	2.6	3.3	3.3	
	Post-Run Workload	3.9	3.6	4.9	5.0	3.9	3.5	4.5	4.7	None
	Communication Workload	4.3	11.8	4.9	12.9	3.9	10.2	5.7	12.5	See Tables C-9 to 24 for time interval data.
	Data Entry Workload	2.4	3.1	3.4	1.9	2.3	2.5	2.9	1.5	
Simulation	Number of Arrivals	9.1	25.5	37.6	64.2	8.8	27.2	34.5	63.5	None
Fidelity	Number of Departures	80.3	25.1	26.5	1.0	79.2	24.5	26.2	0.6	

Note. D - Initial Departure Sector, S - South Sector, R - Rockport Sector, and F - Final One Sector

Table C-3. Quantitative Sector Data: Standard Deviation

		Runway Configuration 27/22L				Runway Configuration 4R/L			
Construct	Variable	D	S	R	F	D	S	R	F
Safety	Operational Errors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Conflict Alerts	0.84	0.41	0.61	1.20	0.17	0.00	0.83	0.92
Capacity	Aircraft Under Control	2.01	2.07	2.88	1.99	3.23	3.23	2.36	3.74
	Average Time in Airspace (min)	0.57	0.47	0.73	1.49	0.49	0.66	0.54	1.18
	Average Arrival Time	0.41	0.49	0.79	1.48	1.04	0.97	0.93	1.16
	Average Departure Time	0.65	0.54	0.78	0.78	0.44	0.61	0.61	0.23
	Altitude Assignments per Aircraft	0.13	0.47	0.26	0.62	0.15	0.21	0.20	0.48
	Average Spacing on Final Approach	N/A	N/A	N/A	13,321	N/A	N/A	N/A	14,032
	Minutes between landings	N/A	N/A	N/A	1.81	N/A	N/A	N/A	2.07
Performance	Data Entries	37.32	47.51	28.95	23.66	75.02	22.31	36.47	22.35
	Data Entry Errors	4.32	4.92	4.29	1.67	4.36	2.57	1.36	0.53
	Number of Altitude, Speed, and Heading Changes	20.56	56.64	22.46	97.82	20.11	20.61	35.77	81.70
Workload	Workload per Aircraft	0.08	0.12	0.12	0.10	0.08	0.13	0.10	0.12
	Average Workload	1.63	1.52	1.68	1.74	1.47	1.58	1.67	1.62
	Post-Run Workload	1.81	1.91	1.52	1.70	1.19	1.29	1.45	1.49
	Communication Workload	0.88	1.18	0.50	0.83	0.43	1.26	0.59	1.52
	Data Entry Workload	0.40	0.95	0.43	0.37	0.78	0.45	0.57	0.35
Simulation Fidelity	Number of Arrivals	0.30	1.21	1.69	2.23	0.55	2.59	1.85	3.60
	Number of Departures	2.05	1.92	1.51	0.77	2.95	1.13	0.93	0.77

Table C-4. Questionnaire Data: Mean Ratings

		Runway Configuration 27/22L				Runway Configuration 4R/L			
	Questionnaire Item	D	S	R	F	D	S	R	F
Performance	1. ATC Services (Pilot)	6.4	7.0	7.1	6.1	6.9	7.0	6.8	6.2
	2. How well did you control?	6.5	7.2	7.3	5.9	6.7	7.1	7.1	6.2
Simulation Fidelity	1. Realism	4.1	4.6	5.7	3.9	5.5	5.2	5.3	5.3
	2. Technical Problems	3.6	3.5	3.5	4.8	2.6	2.5	2.3	2.3
	3. Problem Difficulty	4.2	3.5	4.2	5.2	3.4	3.4	4.9	4.7

Table C-5. Questionnaire Standard Deviation Data

		Runway Configuration 27/22L				Runway Configuration 4R/L			
	Questionnaire Item	D	S	R	F	D	S	R	F
Performance	1. ATC Services (Pilot)	1.69	1.00	0.94	1.20	1.26	0.91	1.14	0.73
	2. How well did you control?	1.29	0.88	0.79	0.99	1.44	0.76	0.92	1.17
Simulation Fidelity	1. Realism	1.45	1.80	2.03	2.03	1.27	1.54	1.27	1.45
	2. Technical Problems	2.58	2.11	2.34	2.15	1.85	1.81	1.18	1.38
	3. Problem Difficulty	1.40	1.63	1.47	1.40	1.50	1.35	1.63	1.30

Table C-6. ARTS Mean Message Entries Per Sector

Message Type	Command	Runway Configuration 27/22L D	S	R	F	Runway Configuration 4R/L D	S	R	F
Data block to another display	**D	0.0	0.3	1.0	0.3	0.1	0.2	1.2	0.2
	**S	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0
	**R	0.5	0.0	0.0	0.2	1.8	0.0	0.0	0.0
	**F	0.0	0.0	0.0	0.0	0.8	0.0	0.0	0.1
	**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Accept handoff using trackball	.	91.7	77.5	92.5	83.8	81.3	67.6	93.1	77.3
Initiate a track	1C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	1X	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Show runway assignment	22L	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Handoff function	B	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
	C	26.5	12.8	18.5	0.0	24.7	13.0	19.0	0.0
	D	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Display beacon code	DA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Handoff function	F	8.2	23.2	35.0	0.0	8.7	23.8	30.9	0.0
Display beacon code	FB	0.8	0.8	2.3	0.0	0.6	0.6	1.1	0.0
Configuration change	FC	0.2	0.7	0.0	0.0	0.6	0.3	0.0	0.0
Display data	FD	0.3	0.5	0.2	0.0	0.8	0.0	0.0	0.0
Display filter data	FF	0.0	0.3	0.3	0.0	0.2	0.3	0.1	0.3
Enter to "H" area	FH	0.0	0.3	0.5	0.0	0.3	0.0	0.0	0.0
Change leader	FL	20.3	10.2	21.5	4.5	9.3	3.4	10.0	1.4
Modify full data block	FM	0.3	0.2	0.2	26.7	0.1	0.1	0.0	17.3
Display preview area	FP	0.3	1.0	0.8	0.3	0.6	0.7	0.4	0.3
Move systems area	FS	0.0	0.3	1.3	0.3	0.3	0.4	0.6	0.2
Move tab	FT	1.3	2.8	2.7	0.8	2.4	2.1	1.4	0.6
Enter to "Y" area	FY	1.0	2.0	7.3	0.0	1.9	1.0	0.8	0.0
Handoff function	HD	0.8	4.2	10.3	0.0	0.3	4.6	0.6	0.0
	M	12.7	0.0	0.0	0.0	11.0	0.0	0.0	0.0
	OL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	R	25.3	0.0	0.0	0.0	25.6	0.0	0.0	0.0
	S	11.7	0.0	0.0	0.0	12.2	0.0	0.0	0.3
	t1	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
	t3	0.0	2.0	0.0	0.0	0.0	0.8	0.0	0.0
	t4	0.0	0.0	2.7	0.0	0.0	0.0	4.6	0.0
Terminate control	TC	5.3	3.5	8.7	0.3	2.0	2.3	4.1	0.4
Visual approach	VA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
Display X tags	X	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Display Y tags	Y	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Uncategorized entries	Others	1.8	4.5	5.0	0.2	7.7	1.4	2.0	0.4
Errors made by CDR; entry type could not be determined.	Recording Error	2.5	10.8	7.7	3.5	10.0	3.4	2.8	5.2

Table C-7. Mean Data For 4R/L Runway Configuration by Sector and Week

		Week 1: No Weather Manipulation				Week 2: Weather Manipulation				Week 3: Weather Manipulation			
Construct	Variable	D	S	R	F	D	S	R	F	D	S	R	F
Safety	Operational Errors	0.0	0.0	0.0	3.0	0.0	0.0	0.5	12.5	0.0	0.0	1.0	3.0
	Conflict Alerts	0.0	0.0	1.0	1.0	0.0	0.0	1.3	1.3	0.1	0.0	0.8	0.9
Capacity	Aircraft Under Control	89.3	53.0	61.5	67.5	88.4	50.6	60.4	62.6	86.5	51.8	60.3	62.8
	Average Time in Airspace (min)	3.2	4.2	8.0	6.7	4.2	5.2	8.6	7.0	3.8	4.3	8.5	9.1
	Average Arrival Time	2.9	4.5	10.8	6.7	5.1	6.2	12.3	7.1	3.9	4.7	11.8	9.2
	Average Departure Time	3.3	3.8	4.2	0.7	4.1	4.0	3.9	0.7	3.8	3.8	4.3	1.1
	Altitude Assignments per Aircraft	1.1	0.7	1.3	3.4	1.4	1.0	1.6	2.8	1.2	0.6	1.4	2.6
	Average Spacing on Final Approach	N/A	N/A	N/A	29,292	N/A	N/A	N/A	22,452	N/A	N/A	N/A	22,086
	Minutes Between Landings	N/A	N/A	N/A	2.7	N/A	N/A	N/A	2.0	N/A	N/A	N/A	2.0
Performance	Data Entries	245.0	155.5	161.0	101.0	199.0	113.3	156.3	109.3	185.8	121.3	191.0	85.5
	Data Entry Errors	7.5	5.5	2.5	0.5	5.3	3.3	2.7	0.7	5.8	1.8	3.3	0.3
	Number of Altitude, Speed, and Heading Changes	225.3	111.8	241.3	599.8	249.6	144.8	289.2	460.6	221.0	117.3	262.0	471.5
Workload	Workload per Aircraft	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
	Average Workload	1.6	1.4	2.3	2.1	2.7	2.4	2.9	3.0	4.6	4.1	4.8	5.1
	Post-Run Workload	3.0	2.8	3.5	3.5	3.7	3.3	4.4	4.6	5.0	4.5	5.5	6.0
	Communication Workload	3.5	8.8	5.2	10.9	4.1	11.1	6.1	13.7	4.1	10.8	6.0	12.9
	Data Entry Workload	2.7	3.0	2.6	1.5	2.3	2.3	2.6	1.7	2.2	2.3	3.2	1.4
Simulation Fidelity	Number of Arrivals	8.8	28.5	35.5	66.8	9.0	26.6	34.2	62.0	8.8	26.8	33.8	62.3
	Number of Departures	80.5	24.5	26.0	0.8	79.4	24.0	26.2	0.6	77.8	25.0	26.5	0.5
Questionnaire	ATC Services (Pilot)	7.5	7.5	7.5	6.5	6.4	6.2	6.4	6.0	7.0	7.5	6.8	6.3
	How Well Did You Control?	7.3	7.5	7.3	6.0	6.0	6.4	6.7	6.2	7.0	7.5	7.5	6.5
	Realism	5.8	4.3	5.0	4.5	5.2	5.4	5.3	5.1	5.8	6.0	5.5	6.3
	Technical Problems	1.5	1.0	1.8	1.5	3.8	3.8	2.4	3.0	2.3	2.3	2.8	2.3
	Problem Difficulty	2.3	2.5	3.8	3.8	3.4	3.5	4.7	4.9	4.5	4.3	6.3	5.5

Table C-8. Sector by Week For 4R/L Runway Configuration Standard Deviation Data

		Week 1: No Weather Manipulation				Week 2: Weather Manipulation				Week 3: Weather Manipulation			
Construct	Variable	D	S	R	F	D	S	R	F	D	S	R	F
Safety	Operational Errors	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Conflict Alerts	0.00	0.00	0.00	1.41	0.00	0.00	0.58	1.15	0.25	0.00	1.19	0.75
Capacity	Aircraft Under Control	4.50	4.24	3.32	5.51	3.05	2.07	1.52	1.34	1.91	4.03	2.63	1.26
	Average Time in Airspace (min)	0.29	0.23	0.11	0.34	0.30	0.62	0.76	0.58	0.27	0.55	0.27	0.44
	Average Arrival Time	0.17	0.29	0.59	0.29	0.43	0.72	1.03	0.54	0.76	0.65	0.32	0.34
	Average Departure Time	0.32	0.82	0.51	0.18	0.32	0.56	0.83	0.22	0.21	0.58	0.33	0
	Altitude Assignments per Aircraft	0.07	0.17	0.12	0.44	0.17	0.15	0.20	0.39	0.09	0.07	0.18	0.20
	Average Spacing on Final Approach (feet)	N/A	N/A	N/A	16,647	N/A	N/A	N/A	12,935	N/A	N/A	N/A	11,767
	Minutes Between Landings	N/A	N/A	N/A	2.64	N/A	N/A	N/A	1.77	N/A	N/A	N/A	1.70
Performance	Data Entries	176.78	23.33	76.37	12.73	55.87	17.62	30.73	13.01	30.35	13.00	12.96	28.73
	Data Entry Errors	6.36	4.95	0.71	0.71	1.15	1.53	1.53	0.58	5.85	1.26	1.71	0.50
	Number of Altitude, Speed, and Heading Changes	14.97	8.46	20.32	57.48	19.91	21.74	41.97	70.25	11.60	5.91	24.91	8.89
Workload	Workload per Aircraft	0.00	0.01	0.01	0.01	0.00	0.03	0.01	0.00	0.01	0.02	0.01	0.01
	Average Workload	0.43	0.38	0.42	0.84	0.30	1.53	0.87	0.25	0.85	0.92	0.65	0.30
	Post-Run Workload	0.82	1.50	1.73	1.91	1.30	0.97	0.89	0.55	0.00	1.00	1.29	0.82
	Communication Workload	0.32	0.92	0.23	0.94	0.23	0.39	0.61	0.59	0.63	0.72	0.35	0.55
	Data Entry Workload	1.80	0.70	1.17	0.03	0.58	0.42	0.46	0.21	0.40	0.13	0.20	0.46
Simulation Fidelity	Number of Arrivals	0.50	3.70	2.65	5.32	0.71	1.34	1.30	1.00	0.50	2.75	1.50	1.50
	Number of Departures	4.12	0.58	0.82	0.96	2.79	1.22	0.84	0.55	1.50	1.41	1.29	1.00
Questionnaire	ATC Services (Pilot)	1.00	0.58	0.58	0.58	1.52	0.84	1.14	0.71	1.15	0.58	1.50	0.96
	How Well Did You Control	1.50	0.58	0.50	1.41	1.58	0.55	1.30	1.48	1.15	0.58	0.58	0.58
	Realism	2.22	2.50	2.00	1.91	0.45	0.55	0.97	0.55	0.96	0.82	1.00	1.50
	Technical Problems	0.58	0.00	1.50	0.58	2.59	2.17	1.14	1.22	0.50	0.96	0.96	1.89
	Problem Difficulty	1.26	1.29	1.50	1.50	1.34	1.00	1.57	1.24	1.29	1.50	0.96	0.58

Table C-9. 27/22L, Sector D - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	17.0	17.3	21.0	24.7	18.1	20.6
	Altitude Assignments per Aircraft	1.2	0.9	0.9	0.9	0.8	1.2
Performance	Data Entries	33.3	33.4	35.8	37.8	36.8	36.5
	Data Entry Errors	1.6	0.9	2.0	1.0	1.2	1.3
Workload	Workload per Aircraft	1.2	0.9	0.9	0.9	1.0	0.8
	Average Workload	2.9	2.8	3.2	3.5	2.8	2.8
	Communication Workload	3.5	3.1	3.1	3.1	3.2	4.1
	Data Entry Workload	2.0	1.9	1.7	1.5	2.0	1.8

Note: All values are averaged across runs.

Table C-10. 27/22L, Sector S - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	10.0	11.5	11.3	15.4	12.6	18.6
	Altitude Assignments per Aircraft	0.7	0.9	1.1	1.0	0.8	0.6
Performance	Data Entries	22.3	21.6	24.8	28.2	27.7	34.0
	Data Entry Errors	1.8	0.3	1.7	1.3	0.2	1.3
Workload	Workload per Aircraft	0.3	0.2	0.2	0.2	0.2	0.2
	Average Workload	2.8	2.1	2.4	3.4	2.9	3.7
	Communication Workload	9.0	7.1	8.7	8.3	7.1	5.9
	Data Entry Workload	2.3	1.9	2.3	1.9	2.3	1.8

Table C-11. 27/22L, Sector R - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	15.1	16.8	10.0	18.0	16.1	13.5
	Altitude Assignments per Aircraft	0.9	1.3	0.8	0.7	1.0	0.9
Performance	Data Entries	32.0	40.4	32.5	38.7	40.0	39.7
	Data Entry Errors	0.5	0.7	0.8	1.5	1.7	1.8
Workload	Workload per Aircraft	0.2	0.3	0.3	0.2	0.2	0.3
	Average Workload	3.5	4.2	3.0	3.7	3.8	3.8
	Communication Workload	3.3	4.4	3.2	3.1	3.9	3.1
	Data Entry Workload	2.1	2.5	3.2	2.1	2.5	3.0

Table C-12. 27/22L, Sector F - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	8.7	18.4	14.2	18.4	21.0	16.9
	Altitude Assignments per Aircraft	1.2	1.7	1.4	1.3	1.3	1.5
	Average Spacing on Final Approach (feet)	39,748	24,070	31,451	31,311	26,561	28,892
	Minutes Between Landings	2.3	2.5	2.9	3.8	2.3	2.7
Performance	Data Entries	17.6	19.7	17.2	23.0	24.0	20.5
	Data Entry Errors	0.8	0.3	0.0	0.2	0.8	0.3
Workload	Workload per Aircraft	0.2	0.2	0.2	0.2	0.2	0.3
	Average Workload	2.2	4.1	3.1	3.9	4.6	4.3
	Communication Workload	10.0	9.3	8.0	8.4	8.0	8.1
	Data Entry Workload	2.0	1.0	1.2	1.2	1.1	1.2

Table C-13. 4R/L, Sector D - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	17.0	16.5	21.1	23.5	17.6	19.5
	Altitude Assignments per Aircraft	1.1	0.9	1.0	0.9	1.0	0.8
Performance	Data Entries	33.1	31.4	34.8	40.3	38.4	31.1
	Data Entry Errors	1.3	0.3	0.7	1.7	1.0	0.8
Workload	Workload per Aircraft	0.2	0.2	0.1	0.1	0.2	0.2
	Average Workload	2.9	2.7	2.8	3.1	3.1	3.6
	Communication Workload	3.4	3.1	2.8	2.7	3.2	6.1
	Data Entry Workload	1.9	1.9	1.6	1.7	2.1	1.6

Table C-14. 4R/L, Sector S - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	9.7	9.2	10.5	13.9	10.6	15.5
	Altitude Assignments per Aircraft	0.4	0.7	0.7	0.6	0.5	0.6
Performance	Data Entries	20.0	19.0	24.0	22.1	20.4	22.9
	Data Entry Errors	0.2	0.2	0.8	0.3	0.8	1.0
Workload	Workload per Aircraft	0.2	0.3	0.2	0.2	0.2	0.2
	Average Workload	2.3	2.3	2.4	2.9	2.5	4.0
	Communication Workload	8.6	7.7	8.3	7.3	7.6	4.3
	Data Entry Workload	2.1	2.0	2.3	1.6	2.0	1.5

Table C-15. 4R/L, Sector R - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	15.0	19.4	8.7	17.8	17.5	16.0
	Altitude Assignments per Aircraft	0.9	1.2	0.9	0.7	0.9	0.9
Performance	Data Entries	25.0	32.3	26.3	34.4	31.3	26.4
	Data Entry Errors	0.5	0.4	0.6	0.6	0.5	0.4
Workload	Workload per Aircraft	0.2	0.2	0.2	0.2	0.2	0.3
	Average Workload	3.2	4.0	1.8	3.0	4.1	4.5
	Communication Workload	52.8	86.5	25.6	51.5	74.3	56.2
	Data Entry Workload	1.7	1.7	3.1	1.9	1.8	1.7

Table C-16. 4R/L, Sector F - 15-Minute Interval Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	7.6	20.3	14.7	15.4	18.6	17.2
	Altitude Assignments per Aircraft	1.4	2.4	2.6	2.0	1.8	1.6
	Average Spacing on Final Approach (feet)	30,663	28,096	24,334	27,878	19,836	21,012
	Minutes between landings	0.0	1.9	2.8	2.7	2.1	1.7
Performance	Data Entries	15.0	17.6	17.8	19.4	14.8	14.9
	Data Entry Errors	0.9	0.1	0.1	0.0	0.0	0.1
Workload	Workload per Aircraft	0.3	0.2	0.2	0.2	0.2	0.2
	Average Workload	2.4	3.7	3.0	3.2	4.1	4.1
	Communication Workload	11.0	8.7	7.1	8.6	9.0	7.0
	Data Entry Workload	2.0	0.9	1.3	1.3	0.8	0.9

Table C-17. 27/22L, Sector D - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.00	0.95	0.94	0.82	0.88	1.35
	Altitude Assignments per Aircraft	0.17	0.14	0.15	0.09	0.15	0.17
Performance	Data Entries	18.05	11.18	6.85	5.31	5.78	5.21
	Data Entry Errors	1.85	1.07	1.67	1.26	1.60	0.82
Workload	Workload per Aircraft	0.17	0.14	0.15	0.09	0.11	0.15
	Average Workload	1.48	1.64	1.63	1.97	1.54	1.73
	Communication Workload	0.59	0.51	0.41	0.53	0.63	2.32
	Data Entry Workload	1.06	0.66	0.35	0.25	0.25	0.31

Table C-18. 27/22L, Sector S - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.47	0.71	1.16	0.84	0.97	1.17
	Altitude Assignments per Aircraft	0.38	0.59	0.44	0.28	0.46	0.18
Performance	Data Entries	11.31	11.47	7.14	5.23	11.91	9.01
	Data Entry Errors	1.83	0.49	1.51	1.51	0.41	1.63
Workload	Workload per Aircraft	0.14	0.12	0.14	0.11	0.12	0.09
	Average Workload	1.36	1.31	1.45	1.56	1.44	1.65
	Communication Workload	0.94	0.69	0.82	0.93	1.24	0.69
	Data Entry Workload	1.14	1.07	0.75	0.35	1.03	0.54

Table C-19. 27/22L, Sector R - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.32	1.32	0.47	0.67	2.02	0.97
	Altitude Assignments per Aircraft	0.21	0.20	0.26	0.16	0.20	0.24
Performance	Data Entries	15.81	12.58	10.13	5.92	2.97	13.78
	Data Entry Errors	0.76	0.76	1.17	1.38	0.82	2.23
Workload	Workload per Aircraft	0.12	0.13	0.17	0.08	0.10	0.13
	Average Workload	1.78	2.01	1.58	1.48	1.79	1.59
	Communication Workload	1.28	0.58	0.76	0.69	0.66	0.69
	Data Entry Workload	1.03	0.85	0.98	0.27	0.39	0.95

Table C-20. 27/22L, Sector F - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.95	1.07	0.79	2.17	1.33	2.23
	Altitude Assignments per Aircraft	0.43	0.58	0.44	0.41	0.51	0.57
	Average Spacing on Final Approach	6,181	8,254	14,443	16,111	13,052	13,334
	Minutes between landings	0.83	1.46	1.59	2.83	1.31	1.53
Performance	Data Entries	7.89	6.82	5.27	5.29	3.52	3.08
	Data Entry Errors	1.16	0.49	0.00	0.41	0.98	0.52
Workload	Workload per Aircraft	0.11	0.09	0.12	0.10	0.09	0.09
	Average Workload	0.98	1.67	1.62	1.74	1.95	1.35
	Communication Workload	1.65	0.96	1.20	1.04	0.89	1.31
	Data Entry Workload	0.87	0.35	0.38	0.26	0.18	0.22

Table C-21. 4R/L, Sector D - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.00	0.97	0.28	0.78	0.96	2.07
	Altitude Assignments per Aircraft	0.12	0.15	0.08	0.11	0.14	0.13
Performance	Data Entries	9.61	19.37	10.49	17.56	17.87	14.52
	Data Entry Errors	1.35	0.50	1.32	1.94	1.41	1.16
Workload	Workload per Aircraft	0.07	0.08	0.07	0.06	0.09	0.10
	Average Workload	1.23	1.28	1.43	1.46	1.51	2.13
	Communication Workload	0.30	0.46	0.35	0.37	0.44	3.24
	Data Entry Workload	0.57	1.24	0.50	0.73	0.93	0.79

Table C-22. 4R/L, Sector S - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.48	1.09	0.66	0.64	0.87	1.81
	Altitude Assignments per Aircraft	0.17	0.24	0.15	0.20	0.14	0.18
Performance	Data Entries	7.84	13.82	8.34	4.99	3.07	8.49
	Data Entry Errors	0.60	0.44	0.83	0.71	0.89	1.69
Workload	Workload per Aircraft	0.13	0.17	0.15	0.12	0.13	0.13
	Average Workload	1.31	1.47	1.44	1.67	1.36	2.15
	Communication Workload	0.59	0.93	0.61	1.09	1.19	1.96
	Data Entry Workload	0.80	1.21	0.86	0.31	0.36	0.58

Table C-23. 4R/L, Sector R - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.41	0.96	0.63	0.44	1.05	1.53
	Altitude Assignments per Aircraft	0.20	0.24	0.18	0.11	0.11	0.27
Performance	Data Entries	11.78	13.97	10.58	7.37	8.61	10.60
	Data Entry Errors	0.82	0.53	0.88	0.88	0.76	0.52
Workload	Workload per Aircraft	0.10	0.06	0.13	0.08	0.10	0.12
	Average Workload	1.54	1.29	0.98	1.39	1.80	1.87
	Communication Workload	0.62	0.32	0.35	0.32	0.57	1.23
	Data Entry Workload	0.79	0.73	1.38	0.41	0.59	0.72

Table C-24. 4R/L, Sector F - 15-Minute Interval Standard Deviation Means

Construct	Variable	1	2	3	4	5	6
Capacity	Aircraft Under Control	0.77	1.18	1.25	1.50	1.61	2.28
	Altitude Assignments per Aircraft	0.37	0.47	0.52	0.41	0.59	0.46
	Average Spacing on Final Approach	5,878	15,254	16,614	15,343	9,576	11,122
	Minutes between landings	0.00	1.23	2.38	2.80	1.84	1.78
Performance	Data Entries	8.39	6.11	4.41	8.73	5.63	8.53
	Data Entry Errors	2.70	0.33	0.33	0.00	0.00	0.35
Workload	Workload per Aircraft	0.17	0.07	0.12	0.11	0.10	0.08
	Average Workload	1.14	1.52	1.63	1.68	1.70	1.55
	Communication Workload	1.71	0.71	1.04	1.65	1.54	1.51
	Data Entry Workload	1.14	0.31	0.35	0.62	0.27	0.49

Appendix D
Controller Comments

The following data represent controller responses (edited for grammar) to Sections D.1, D.2, and E of Final Questionnaire. Responses for Section D.1 focus on improving specific components of the ARTS IIIA console. Responses for Section D.2 consist of mistakes controllers commonly made using the ARTS IIIA console and potential causes of these mistakes. Responses on Section E concern the baselining effort.

WEEK 1

Controller Responses to Section D.1

The scopes lack consistency in all areas of radar and alphanumeric function displays. Eliminate existing trackball and keyboard, replace with mouse, and keyboard with windows. All tied into NAS. Get better weather displays. An interface between the ARTS tag and the NAS would be helpful (i.e., when making an entry on an ARTS tag such as altitude, aircraft type, could be interfaced to eliminate the FDIO data entry).

Radar maps could be sharper. This is the only equipment I've worked with. I've learned, through the years, to become efficient in the way I interact with the equipment. I am working with simulation equipment that has a radar display using a windows-type program. It is very easy to use, it allows the controller to tailor the position to his/her liking. It has been my experience that a mouse is not as effective as a trackball. The mouse isn't stationary and easily misplaced. Also a mouse is not as durable as a trackball.

Map displays should be more precise. We are supposed to stay 1.5 miles from a boundary; however, there are times the boundary line is 1 mile wide itself. A finer line would reduce error. Keyboard: The current configuration is not user friendly. A keyboard more like a computer keyboard would be easier. Trackball: If we had a system where you could touch the screen for a handoff, etc., then you wouldn't need a trackball. ARTS characters: Right now, there are four preset sizes and only two are even close to being usable. A better method changing character size would be good.

We are limited to what we can enter into the keyboard because of the programs (i.e., we are unable to enter an IFR flight plan into the NAS system using our keyboards). Center can do this function. It would cut down on our workload if we were able to accomplish this in the terminal environment.

Supervisor Response to Section D.1

I am an avid fan of a windows-based system with feature such as pull-down menus, multi-tasking (window in a window), mouse applications vs. slow trackball. Maps need to be digitized and displays enlarged to not only be more useful but provide additional working space at the console.

Controller Responses to Section D.2

Some keyboard commands are quite lengthy and when traffic builds up it's easy to mis-hit the keys...maybe the keyboard is too small?

Sometimes people will ship the aircraft to the next sector thinking the handoff has been accomplished because of his position and not his data block. Maybe a color change would show a handoff.

Overall the keyboards work well but when they start to stick, it creates much more workload on the controller.

Supervisor Response to Section D.2

In the environment that currently exists, you constantly fumble for the knobs. A system that is more user-friendly for adjusting scope presentation would enhance the system tremendously. More room is needed for work space in front of the PVD.

Controller Response to Section E

Shorten problems to one hour. Increase the traffic volume to final and add a second final controller.

Supervisor Response to Section E

To us, the ARTS IIIA console is "home." If you were to replace our consoles at Boston with ARTS IIIE equipment, it would probably excite everyone! My point is, design a system that will make all users (IIA, IIIA, IIIE) excited with the change. Let's take advantage of what we have seen with 20 in screens and color presentations and integrate these products into the replacement cycle for "all" systems, regardless of what currently exists. I know that the intent in development is heading in this direction but it is crucial to continue to emphasize this point. If we are baselining, let's establish the criteria for today's technology as a start and continue to build from there. The foundation needs to be technology from 199-now!

WEEK 2

Controller Responses to Section D.1

Reliability of ASR-9 radar; Reliability of ARTS: Less system crashes or scatters, no false targets, no software problems. Setup - automatic, personalized display brightness setup via computer card or access code.

There is too much glare in the glass. Not enough room to write if needed--trackball and keypack get in the way. The console knobs can be difficult to identify.

Radar maps and display: Digital display would be much better than analog. Keyboard entries should be integrated into the NAS and FDIO. The ARTS IIIA interface should be more user-

friendly. The scope set procedures are cumbersome, and it would be nice if it could be automated.

A larger workspace would be nice. Trackballs frequently fail or work improperly causing controller stress to rise. I realize ARTCC and terminal duties are different--however, being a former en route controller, I think the NAS PVDs are much more efficient and user-friendly than ARTS IIIA equipment is. Additionally, my experience has been that the NAS equipment is much more reliable than ARTS IIIA equipment.

Supervisor Response to Section D.1

Map displays should allow labeling of airways, routes, fixes, blocks of airspace, altitude stratums (not that all of these would be used simultaneously, but at ATC's preference) in subdued colors. Alphanumerics should have capability to be enlarged or reduced with set sizes. WX should have color capability. Primary and beacon returns should have different shades of color. Controls should be grouped by similar function (i.e., beacon and primary together, display intensity and adjustments together). Work areas should have non-equipment-cluttered writing areas. Keyboards should be close to QWERTY w/F keys.

Controller Responses to Section D.2

Slightly missing targets or keyboard alphanumeric keys.

Keyboard often sticks and it can be difficult to find the preview area among the alphanumeric. The slewball has to be almost right on the headset in order to have an effect i.e., difficult during heavy traffic.

Keyboard often goes haywire with random and/or rogue entries appearing without controller input. Additionally keyboard entries are often cumbersome and/or lengthy which causes me to divert my attention from traffic control duties. Often have difficulty in distinguishing and selecting correct data blocks with trackball(s).

Supervisor Response to Section D.2

Alphanumerics are difficult to read, especially since letter exit fixes shared with altitude information. M350 is turned N-BND, N350 turned S-BND, sometimes misread aircraft is turned wrong way. Know adjustments are difficult in the dark environment, often involve guessing which knob, watching what happens when you turn it, and trying another guess. Keyboard entries FDIO are QWERTY, ARTS is alphabetized creating hunt and peck. Many format errors because of vertical display of entry information, makes spacing functions hard to detect. FP changes should be accomplished through radar console, not by having to move over to FDIO and changes. Complete flight plan information should be displayed at position with edit capability (windows).

Controller Responses to Section E

[Sim] Pilots and software used to help them control traffic need improvement.

The work we did with simulation was good but frustrating. The realism could be improved by better aircraft compliance.

As far as this study goes, every attempt at realism must be achieved or attempted. Current active controllers must feel challenged and feel like the simulation is real to get maximum participation out of the scenario. Sim pilots and sim pilot software must achieve more operational consistency to achieve better realism; try and make/request sim pilots to become more aware of aviation/ATC phraseology again in an effort to promote realism. Can we have more scenarios (i.e., other runway configurations 33/27, 22 just to prevent complacency from controller study group)?

Supervisor Response to Section E

Perhaps realism should be explained to the team. What you may consider realistic could be very different from the sensitivity of realism the controllers have. What you need for study purposes probably is not as detailed as what controllers may be expecting for realism and, if this is explained to them, they may not be as frustrated when things get silly. Make sure there are no surprises. Brief talks on problems with aircraft compliance of ATC instructions whether it's software, pilots, etc. They should know crazy turns could happen, don't get frustrated, hang with it, it's not a reflection on ability. Supervisor/SME should know their role involved SME evaluation of controller's, logging problem events, and acting as a TRACON supervisor, sometimes all at the same time. Visit to SIMOPs would help ATCs understand the equipment and limitations of the pilots--reduce frustration.

WEEK 3

Controller Responses to Section D.1

Radar and Map displays should be sharper and clearer and possibly color to display "shelving" more readily. Keyboard lights are constantly burning out or too bright compared to other buttons alongside. Too many entries are required for seemingly simple operations: multi-function key, green keys, and so on. Console switches and knobs: just plain old and outdated. Basically, functions should be able to quickly and readily let a controller make an entry so his eyes can go back to the radar screen sooner. Possibly and voice-activated-system of recognizing what aircraft you're talking to and being able to enter data by just saying it (i.e., handoff or call sign being entered just by speaking it, for VFR pop-ups). This would always let the controller keep his eyes on the screen. A big plus! Thank you!

Workspace: console is too narrow to write on a normal 8 1/2 x 11 paper. Keyboard: not typewriter oriented therefore limits workspeed. Switches: mechanical and worn, resulting in rough movement. Trackball: Sticky, no regular movement. Radar: full data displays of flight plans should be available on the scope, as well as the capability to amend that information at the scope. Other: Real time data on other monitors should be available in a windows format, such as wind, altimeter, and weather. Now that information is placed in three different locations. A display that could operate lighted conditions would be beneficial. The first few minutes of each controller's session on a particular position is spent setting it up the way he/she likes it. It would seem to free up some scanning time if the new equipment had a programmable memory of each

controller's desired setting. Extra voice coordination could be eliminated via a message sending more from screen to screen.

The maps on all ARTS IIIA have not been what I'd like to see. They are usually too wide, out of alignment, and out of focus. I'm left-handed, as far...keypack position needs to be identified. The FDIO/Host computer should be able to be connected into ARTS--that way amendments, flight plan information, WX information, is all right at your position.

The radar and map displays tend to usually become washed out or become enlarged to the point where it takes your attention away from your primary duties. We need a system that will provide radar coverage from the surface, and that will not be affected from obstruction or terrain. The keyboard would be more user-friendly if it was moveable to allow for personal comfort. The console and switches are usually either too touchy where they become very hard to use or they don't work as they should, causing the controller to sometimes not get the best display possible (i.e., weather radar). The keypack should be moveable - the display should be of a brighter and have more contrast than now. The video maps should be more constant (less blooming and thinner lines.) You should also be able to look at flight plans on radar console and make changes to the flight plans and the radar console. This would reduce workload because the need for coordinating these changes would not be necessary. In addition, the interface between facilities could be improved.

Supervisor Response to Section D.1

Radar and map displays are never exact. They are often blurred, washed out, and usually misaligned. Keyboard hardware and trackball hardware are always in need of repair/adjustment or replacement. The ease of using the trackballs varies with each position. Many of our ARTS entries have become too lengthy. They are difficult to teach because there are too many of them. These entries also do not allow for minor errors such as a space or character too many. A bad entry is not easily corrected and must usually be completely re-entered. Moving the preview and systems areas and the various tab lists should be a click and drag function that does not require a keyboard entry. Keyboard should be adaptable for left-handed individuals.

Controller Responses to Section D.2

The amount of keys to hit when making various entries requires attention to be diverted to looking at keyboard when you need to be constantly watching scope.

Entries - selecting wrong keys. Trackball - hard to discern to the slew overlapping targets. Switches and knobs - decentering the presentation is tricky because it is touchy. You must very gently turn the knob in order to avoid the 'picture' going off the scope. But sometimes it still happens.

Not knowing why many times the ARTS information/tag doesn't auto acquire when all of the correct input is there for no rhyme or reason. When changing flight plan information to get the ARTS IIIA to coincide with the FDIO/host computer is much more difficult than it should be.

On a day-to-day basis, we are forced to use several different functions that are time consuming, and make controller take eyes off the radarscope. The trackballs are not always easy to use; they sometimes stick.

Supervisor Response to Section D.2

Errors in entries are not always easy to recognize. Depending upon where the ARTS preview area is, a controller might make several entries before realizing that none of them was accepted because of the first bad entry. Often the tab lists, systems areas, preview areas, etc. will obscure aircraft targets and ARTS tag information.

WEEKS 1-3

Supervisor Responses

D.1. Digital displays with color could/would provide a more effective way of displaying data of varying types (i.e., weather, maps, data blocks). The current volume of workspace is inhibitive to complete necessary forms or tasks as required nationally or locally (i.e., PIREP forms, sign in/out forms). Current switches and knobs are not properly labeled as a result of function changes with new ASR9 systems and are quite cumbersome to operate smoothly (particularly decentering displays). ARTS IIIA interfacing within the NAS system is generally misunderstood by controllers. We would like to have the functionality/capability to effectively cause a change in the data block transferred to the actual flightplan rather than duplicating some efforts through FDIO/FDEP equipment. Calling up information such as provided by FDIO/FDEP at the radar position would be a welcomed addition. The keyboard is cumbersome, fails to follow keyboard standards, and results in spending too much time looking away from the radar display while entering information. A more intuitive interface may reduce/eliminate the keyboard for controllers and use a built-in system within the display. Maps and their clarity of display on a PVD would/could be sharp/well-defined in a digital format, also permitting real-time editing for the local facility. I would, overall, like my position/display to give me anything that the NAS has to offer with regards to expected traffic loads, full flight plans, weather data, and administrative data (i.e., sign on/off currency tracking). Perhaps diagnostics can be enhanced and reliability of using equipment that is proven sound (off-the-shelf) raised.

D.2. I think lighting is a great deal of concern when trying to quickly identify the correct key and/or adjustment knob or switch. Alphanumerics on radar displays are poor in resolution and readability of an "S" to a "5" under a quick scan can result in misreading a call sign or data information.